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20 July, 1900.

56TH CONGRESS, 1st Session. } SENATE. { DOCUMENT No. 30.

REPORT

BY

Laurence
ELMER L. CORTHELL,
DELEGATE OF THE UNITED STATES - Dept. of State
(REPRESENTING THE STATE DEPARTMENT)

TO THE

SEVENTH INTERNATIONAL CONGRESS OF NAVIGATION,

HELD AT BRUSSELS, BELGIUM, JULY, 1898.

DECEMBER 12, 1899.—Referred to the Committee on Commerce and ordered to be printed.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1900.

Sci 1525.25

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DEPARTMENT OF STATE,
Washington, December 11, 1899.

SIR: I have the honor to transmit herewith for the information of Congress the report of Mr. Elmer L. Corthell, a delegate from the United States to the Seventh International Congress of Navigation held at Brussels, Belgium, July 18, 1898.

I have the honor to be, sir, your obedient servant,

JOHN HAY.

Hon. WILLIAM P. FRYE,
President pro tempore of the Senate.

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INTRODUCTION.

The preliminary report, dated January 16, 1899, which follows this introduction, gives the general information relating to the International Navigation Congress held at Brussels in 1898. Referring to that, to avoid repetition, the following is an amplification of the general statement given in that report, and is taken from remarks made by the author before the American Society of Civil Engineers at its annual convention held at Cape May June 27, 1899:

The scope of this congress is intended to and generally does now embrace the following subjects: Canals, canalized rivers, ship canals, river improvements, entrance channels, ports, and harbors, their construction, maintenance and operation, practical questions involving appliances, plant, methods of navigation, etc. Papers are written upon these subjects. They are discussed and the questions are decided upon by the congress itself. In organizing a congress the method generally followed is for the government of the country where the congress is to be held to invite other governments of the world to send their delegates. Invitations to the congress at Brussels were sent out by the minister of foreign affairs, corresponding to our Secretary of State. Invitations were extended to all foreign governments, and the organizing committee invited societies, organizations, etc., to send delegates.

There were 121 government delegates, representing 24 nations. Then there were delegates of municipalities, engineering and other technical societies, chambers of commerce, navigation associations, and commercial and industrial organizations of various kinds interested in any way in the subject of navigation. Of these there were 410 delegates. Twelve engineering societies were represented by regularly constituted delegates. There were 59 of these delegates. Twenty cities were represented as cities, with 34 delegates. There were 37 chambers of commerce, with 56 delegates. There were 75 navigation and commercial organizations, with 45 delegates. There were industrial and agricultural societies; manufacturers, like manufacturers of dredging machines; the John Cockerill Works at Seraing and other similar works; steamship companies; ship-canal companies; in fact, the whole range of navigation was represented at that congress. There were private members in addition to these, numbering 840; that is to say, not delegates of governments or municipalities. The total membership was 1,371. Of these, 862 were from countries other than Belgium. There were in all 35 nationalities represented. The number of civil engineers was about 600.

Comparing this congress with previous congresses, there were at The Hague in 1894, 1,048 members, with 20 nationalities represented. At Paris in 1892 there were 1,042 members, with 22 nationalities represented. At Brussels in 1885, which was the earliest congress, there were 407 members, with 13 countries represented. This last congress at Brussels was held under the "high patronage" of His Majesty King Leopold, King of the Belgians, who took really an active interest in it. There were 4 honorary presidents; one was Prince Albert and the others were the ministers of

three of the departments that have to do with such matters. One of these ministers, the minister of agriculture and public works, presided at several of the meetings. You will see from this that the Government itself took an active interest in the proceedings. There was a committee of patronage of very distinguished men from all over Belgium. There were two general presidents, one of whom was always present at the meetings, and they were men who held important positions in the Belgian Government. There were various committees which organized the congress. In the preparation of this congress there was a committee of organization which arranged the subjects of the papers and sent them out in the fall and early winter of 1897, inviting papers on the subjects.

There were 71 regular papers sent in, of which 20 were in German, 6 in English, 4 in Dutch, and 41 in French; 1,066 pages in all, and 123 plates. There were also presented 25 to 30 papers which were either too late to be admitted or were on subjects not comprised in the regular list of questions. The regular papers were printed and sent to the members of the congress in time to be read before the meeting took place in Brussels. The papers, consequently, were well known to the members before they came to Brussels. The report of which I spoke in the beginning of my remarks and which I am preparing will contain about 200 printed pages, with about 115 plates, which will be bound with it, and I hope this will be published by Congress, as the preliminary report was, and distributed, so that members of this society can have the use of it.

I may add that between 600 and 700 members were present at the meetings. It was probably one of the largest congresses in the way of personal attendance that has ever been gotten together on any subject connected with engineering and navigation. The Belgian Government provided two very suitable buildings for the holding of this congress. * * *

But the object of these navigation congresses is to get at something useful, and consequently the entire trend of discussion in the sections on every subject was with that purpose in view; and after the discussion was carried through on each subject, there was a vote taken in that section upon the points that were raised on a motion in reference to the question submitted. That would be the decision of that section. Then afterwards these sectional decisions were referred to the full congress and there a vote was taken upon them. So that what we get as the result of that congress is of great utility, because it shows the consensus of opinion on many important matters affecting navigation, construction, maintenance, and operation. I need not go into the subject of excursions. That was splendidly attended to by the people in Brussels. Special trains were furnished us, and 600 or 700 members, with some ladies, visited Ostend, Bruges, Heyst, Antwerp, and Seraing. King Leopold gave an evening reception in the royal palace, and everything was done to not only give us a useful congress, but also great pleasure. Everything was conveniently arranged. Each morning we found in our boxes—every man had his box—a résumé of the previous day's work in print and with a programme of that day in full detail. If an excursion was projected the programme would give the information when you were to go to the train, and when you were to arrive here or there, and when you might return. It was one of the most complete organizations for comfort and for useful work that, I think, ever undertook such service.

Following the preliminary or general report is the detailed report, consisting entirely of the résumés of the papers presented to the congress by writers from various countries upon the questions contained in the programme, which were sent out by the organizing committee many months in advance of holding the congress. The questions treated appear in the table of contents. The printed papers, as they

came to the writer, were mostly in French, and for this reason there has been a long delay in submitting the detailed report. There were more than 1,000 pages of printed matter to be carefully read and studied and put into the English résumé. It has been the object of the writer to avoid, as much as possible, the repetition which would naturally happen in papers written on the same question by several writers from different countries, and to give in the résumés what would be of value especially to American engineers and commercial men, omitting often what would not be of value to them. The plates which follow the detailed report and are referred to in it, often give a much more complete and clearer idea of the subject-matter than the text itself, although the weights and measures in the plates are given in the metric system. In the text they are given in the same system, but the conversions into English weights and measures have generally been made, and they appear in adjoining parentheses.

It will be noticed by the reader of the detailed report that the attention of the congress was mostly given to inland navigation, although the commercial facilities of maritime ports are treated at some length. It is expected that the Paris congress, to be held in 1900, will give more attention to the maritime features of the general subject—breakwaters, dikes, and other constructions, which form maritime harbors, and in which this country has a great interest on account of its extensive shore line and its comparatively few natural harbors, requiring important and expensive constructions to make safe and deep-water ports.

CHAPTER I.

PRELIMINARY REPORT.

NEW YORK CITY, *January 16, 1899.*

DEAR SIR: I have the honor to submit the following report upon the Seventh International Congress of Navigation, held at Brussels, Belgium, the latter part of July, 1898:

The congress at Brussels was the first to combine inland and maritime navigation. Previously there had been held at irregular intervals two congresses, one an inland congress and the other a maritime congress. The first series held its first congress at Brussels in 1885, and since then they have been held at Vienna, 1886; Frankfort-on-the-Main, 1888; Manchester, 1890; Paris, 1892, and at The Hague in 1894. There have been held two congresses on maritime navigation, the first at Paris in 1889, the second at London in 1893. In accordance with a resolution adopted at The Hague in 1894, the congress at Brussels was to consider questions relating to both inland and maritime navigation.

Briefly, the organization of this congress was as follows:

The membership comprised three classes: First, Government delegates; second, delegates accredited by cities, navigation societies, railway companies, chambers of commerce, and technical, scientific, and industrial associations; third, private members, who became so by application and by payment of a subscription of 25 francs ($5).

The programme of the questions to be submitted for deliberation by the congress was made by the organization committee, and they called upon members for preliminary reports to serve as a basis for the discussions.

The work of the congress included general meetings, section meetings, and excursions. All the questions to be considered were first read and discussed in the section meeting and subsequently discussed and the results agreed upon in the general meeting. The congress board, which had general supervision of the proceedings, consisted of general presidents, general secretaries, and assistant secretaries of the organizing committee, as well as several foreign vice-presidents and secretaries. The boards of the sections consisted of a Belgian president and secretary appointed in advance of the congress, who attended to the

preliminary arrangements in their sections, and also several foreign vice-presidents and secretaries. The organizing committee designated some foreign members as members of the congress board; also vice-presidents and secretaries of that board.

There were five sections, embracing, first, canalized rivers; second, inland canals; third, tidal rivers and ship canals; fourth, seaports; fifth, tolls.

After a complete discussion of all the questions each section appointed one or more representatives to present at the general meeting the conclusions adopted by the section.

The general subjects above mentioned were discussed by questions, on which papers were presented previous to the opening of the congress. There were eighty of these papers regularly presented, besides quite a number irregularly presented; that is, upon the initiation of the writers themselves and upon subjects that did not belong to the programme of the congress, or were presented after the date fixed for the presentation of the papers. These irregular papers were translated into French, if they were not already in French, and printed at the expense of the writers. They were simply distributed among the members by the officers of the congress.

The above regular papers, comprising about 1,000 pages of printed matter, mostly in French, will be presented as a part of this report, either by giving a brief synopsis of the less important papers or a full résumé of those that would be considered of greater value in the United States. At this point only the general subject of the questions will be stated, in order that the scope of the business of the congress may be appreciated; the details of these subjects will be stated in connection with the synopsis and résumé to be given hereafter. The subjects discussed are as follows:

FIRST SECTION.—*Canalized rivers.*

First question: Raising of existing weirs (barrages).

Second question: Consolidation of weir foundations.

Third question: Utilization of the fall of water at weirs as a motive force.

Fourth question: Resistance to the movement of boats.

SECOND SECTION.—*Inland canals.*

First question: Modes of mechanical traction along canals.

Second question: Single-lock gates.

Third question: Means of securing the impermeability of the bottom and sides of a canal.

Fourth question: Mechanical raising from reach to reach of water supplying a canal.

THIRD SECTION.—*Tidal rivers and ship canals.*

First question: Formulae of the characteristics of a tidal river.
Second question: Modes of estimating the cube of tidal volumes.
Third question: Means of consolidation of ship-canal banks.
Fourth question: Dredging.

FOURTH SECTION.—*Seaports.*

First question: Warehouses and sheds.
Second question: Relative surfaces of the different parts of a seaport.
Third question: Free ports.
Fourth question: Single-lock gates.

FIFTH SECTION.—*Tolls.*

First question: Maritime tolls and local rates; mode of collection.
Second question: Unification of the gauging system of inland boats.

There were over 1,000 delegates, from 20 different countries. These governments were represented by 106 government delegates.

About the 1st of March, 1898, I received from Hon. John Sherman, then Secretary of State, a commission as delegate of the State Department to the congress, the same being dated February 10. In a letter dated February 14 from Mr. Sherman, he informed me that my colleague would be Capt. John Biddle, Corps of Engineers, U. S. A., designated by the Secretary of War. On account of the lateness of my appointment it was impracticable for me to prepare a paper which must, according to the rules of the congress, be submitted by March 1. I had had in mind for some time the preparation of a paper, if I should receive the appointment as delegate, but the subject upon which I had been preparing for a year a large amount of data was found to be outside the programme of the congress. After considerable correspondence with the general secretary of the congress, who suggested that the paper should be presented as one of the irregular papers above referred to, the translation and the printing to be done at my own expense, and also upon referring the matter to the then Secretary of State, Mr. Day, I declined, upon his advice, to submit the paper under these conditions.

I may also add that Captain Biddle proposed to write a paper on a special subject, and this also was found to fall outside of the regular programme of the congress. The subject upon which I had proposed to write was "Maritime commerce, past, present, and future." Finding it impracticable to present the paper to the congress, I completed it and presented it to the American Association for the Advancement of Science, which held its fiftieth anniversary in Boston the latter part of August this year. I have had an English and a French edition of

this paper printed and have distributed it to engineers and others in various parts of the world, who furnished me much of the data for the paper. I am pleased to send a copy of this to you with this report.

You will see from the rules of the congress, of which a brief résumé is given above, that its main object was to discuss and deçide questions of practical interest and to issue these decisions as a consensus of opinion of a large number of practical men from various parts of the world. This method makes the results of such a congress of much more value than were the results of congresses held like those at Chicago in 1893, where, generally, there was no discussion upon the questions presented.

A general meeting was held as the final session of the congress, and at this meeting the decisions arrived at in the various sections were presented to the full congress for its discussion and decision.

In order that this report may have the greatest possible value, its order will be as follows: First, this preliminary statement in regard to the organization of the congress and its methods; second, the synopsis and résumés of the papers presented and of the discussions; third, the conclusions in full that were reached at the above-mentioned final meeting of the congress. In addition I have, by correspondence with the officials of the various Governments of Continental Europe, obtained and transmit with this report, first, a statement in regard to the internal navigation of these countries, when obtainable, and, second, the latest charts of waterways of the following countries: England, France, Belgium, Holland, Germany, and Russia.

The programme of the congress was admirably arranged for work, examination of interesting works, and for recreation. The sessions were held in two of the Government buildings, well adapted for the purpose of accommodating the large number of delegates, of which there were estimated to be about 700, at the meetings of the various sections, as well as two full meetings of the congress. The excursions, which were in every case to objects of great commercial interest, included Bruges and Heyst, where there is now under construction a ship-canal from the North Sea to Bruges, Ostende, Antwerp, and the great John Cockerill works at Seraing.

Nearly every evening the members of the congress were entertained by receptions, generally by officers of the Belgian Government, one of them being by the King of the Belgians, who also invited the members to visit the royal park at Laeken. The municipality of the city of Brussels also gave a general reception at the city hall. There was also a banquet in the large banquet hall of the Brussels Exposition Building, to which were invited not only members of the congress, but distinguished people from various parts of Belgium.

Before entering upon the résumés of the papers, I think it would give you pleasure to know that as the representative of the United States, and, due to the peculiar conditions existing in the United States

at that time, the only representative, I received as such the most cordial reception and the kindest attention, and it may not be improper to state that as this congress was held in the latter part of the last week in July, and after our Government had been victorious in the war in which it was engaged, the reasons for this cordial reception may be imagined, it being really due, in my opinion, to a radical change of sentiment that had taken place everywhere in Continental Europe in regard to the United States.

As above stated, it was impracticable for me, as the representative of the United States Government, to present a professional paper, for the reasons given, but when called upon at the last and full session of the congress to make some remarks as the representative of the United States, and appreciating the splendid work of organization and execution by the Belgian committee, which had charge of the congress, I made brief remarks refering to this subject; and while making them, upon the raised platform near the organization committee, it was intimated to me by leading representatives of Great Britain and of South America, who were near me, to include these countries also in my thanks to the organizing committee. I therefore take the liberty of inserting these remarks at this point.

[Remarks of E. L. Corthell, delegate of the United States, before the general meeting of the Seventh International Navigation Congress, July 30, 1898.]

Mr. PRESIDENT, LADIES AND GENTLEMEN: The public work of this congress is now closed. It is fitting that we should for a moment consider it.

All such congresses mark epochs in the history of navigation. This one, above all others, marks a great step in advance. It will promote all navigation interests in a marked degree. It will assist materially in solving the great questions of navigation now preparing for correct solution. It will place in the libraries of the twenty countries represented here the results of the valuable experience of the men who have done the work of which they write and about which they discuss—the practical men of affairs who have been willing to bring to this congress, in one form or another, the very essence of the questions before it for solution. The literary product of this congress will be a veritable encyclopedia of information for reference.

Having had something to do in organizing the great International Engineering Congress, held at Chicago in 1893, to which many whom I see now before me contributed most important and valuable papers, I have some knowledge of the kind and amount and difficulty of the work which you gentlemen of the organizing committee have had to do to prepare for and to arrange and to carry through this great congress; and your work is not yet complete, for you must compile, edit, and transmit to us in various parts of the world the results of the congress. These results will aid us in the important questions and works under our charge.

To my own country the lessons learned here will be of great value—that new and great country with an immense coast line, with few natural harbors, with rivers whose volumes are great, whose conditions are difficult to master, and whose extent is almost phenomenal—one river alone having 16,000 miles (about 25,000 kilometers) of navigable waters—great lakes with connections to be made to the seaboard, canals to be constructed, and many rivers to be canalized.

To help us and the engineers of all countries, you, gentlemen of the organizing committee, have done successful and splendid work. You have also, with rare skill,

carried through with eminent success the actual work of this great body of from 600 to 900 delegates present. And not only have you satisfactorily managed the sessions—distributed the various and other necessary matter—but you have attended to all social and excursion features in a way to compel our admiration and to give us unbounded pleasure.

Therefore, on behalf of the engineers of my country; on behalf of the American Society of Civil Engineers, which requested me to appear as its representative; on behalf of my colleague delegate, also of the United States Government, and who is unable to be present; on behalf, also, of my English friends across the channel; and on behalf, also, of all the American countries who have sent their distinguished delegates to the congress; and, finally, on behalf of the United States Government, I sincerely thank you for all the magnificent and arduous work you have done for us and for the navigation of the world.

The résumé of the papers (80 in number) presented to the congress, and of the lengthy discussions in the sections upon them, will be forwarded as soon after the discussions are received as will be found practicable to write the résumés in English.

In the meantime the conclusions arrived at by the sections and by the congress itself are given at this point to prevent further delay in the submission of the report.

CONCLUSIONS ADOPTED BY THE CONGRESS.

FIRST SECTION.—*Canalized rivers.*

First question: Raising of existing weirs (barrages).

1. The raising of the water level retained by a movable weir, within limits not usually exceeding 1 foot 8 inches to 2 feet, is easily accomplished at a reasonable cost, and can be carried out by the ordinary methods without hindrance to the navigation, whatever may be the system of weir.

2. The essential conditions which the transformed weir should fill are: A sill affording a perfect guaranty of stability, and anchorages capable of resisting the increase in the strains resulting from the raising of the water level of the reach and from the alterations in the appliances for closing the weir.

3. In cases where the sill or anchorages are of inadequate strength the extent of the work is considerably increased; and, in order to maintain the navigation, it becomes necessary to construct cofferdams of the ordinary type, or to employ water-tight caissons, or even to resort to compressed-air foundations.

4. The raising of the water level augments the difficulty of working the weir, and necessitates a more thorough supervision if it is desired to avoid the flooding of riparian lands. It possesses, however, on the other hand, the very great advantage of enabling the weir to be less frequently opened or closed, with great benefit to the navigation and the preservation of the works.

5. The increase of depth effected by dredging, combined with the rectification of the banks, may, under certain circumstances in the conditions of the régime of a river, furnish a satisfactory solution, as shown by the results obtained upon the Severn in England.

Second question: Consolidation of weir foundations.

1. The exact determination of the causes to which leakages through or along the edges of a sill are to be attributed leads at the same time to the solution of the difficulties which it is proposed to remedy.

2. The method consisting in utilizing the upstream pressure for closing the openings, by introducing into them materials able to block them up, has proved effective and adequate in certain instances, notably on the Belgium Meuse, where most excellent results have been obtained by the employment of lead mats.

It would be unwise to regard this process as universally applicable, its success being often due to certain conditions and the great care bestowed on its execution.

3. If, therefore, a durable and assured protection is required, it is necessary to have recourse to thoroughly water-tight protective works, carried down to a sufficient depth on the upstream side of the sill.

Metal piles and sheeting, the use of which has been advocated, may for this purpose prove serviceable, if experience confirms the propositions and the perfect impermeability claimed for the method by its proposers.

4. The protection of the downstream side of the sills, which on certain rivers constitutes an important inconvenience in the maintenance of the works, can be readily secured by the construction of a masonry apron, shaped so as to lessen the effect of the current and eddies, while preserving the requisite conditions of resistance for the sill itself.

Third question: Utilization of the fall of water at weirs as a motive force.

The congress considers that it is expedient (*a*) to urge engineers to investigate the means of applying the power of the fall of water on canalized rivers to the working of the machinery of weirs and locks as well as to the traction of boats when traversing the navigable passes and locks; (*b*) to retain on the programme of the next congress the investigation of the processes suitable for utilizing the available power resulting from the existence of canalization works for the mechanical or electrical traction of boats, not merely under ordinary conditions, but also in flood time.

The congress expresses the hope that the power of the fall of water will be reserved in principle for serving the navigation, and will only be alienated after much circumspection, in the first place to public purposes, and afterwards to private concerns.

Fourth question: Resistance to the movement of boats.

In view of the considerable interest attaching to the experiments on the resistance of boats to traction and the importance of the results already obtained, the congress considers it desirable to continue the investigations with boats and by the help of models, simultaneously, so that one set of experiments may be checked by the other.

These experiments should be carried out on open water as well as on rivers and canals; and account should be taken of all the circumstances which may be of practical interest.

A twofold result will thus be obtained:

(1) Of determining the best form of boats for inland navigation according to the service for which they are destined.

(2) Of determining rationally the general cross section of canals in accordance with the type of boats intended to navigate them.

The congress, moreover, trusts that the Governments and the navigation companies will continue their assistance in these interesting researches.

SECOND SECTION.—*Inland navigation canals.*

First question: Modes of mechanical traction along canals.

The second section, after having heard the explanations given by the various authors of the reports on mechanical traction, and having discussed the various processes tried since the Hague congress, has thought it necessary to select a certain number of results from the trials made, which may serve to guide future investigations and experiments. These results are as follows:

1. Traction of barges in trains by tugs and towing vessels must be reserved for rivers and canals with long reaches of large cross section and having locks sufficiently large to receive a whole set of boats together, and also for special portions of the waterway, such as tunnels, or sections presenting exceptional inconveniences.

2. On canals of more limited cross section, like those of France and Belgium (ship canals excepted), traction singly should be adopted, to avoid all loss of time and stoppages, both in making up trains and in passing through the locks.

3. The speed of navigation must be determined in relation to the cross section of the canal and of the boats to be towed, so that the strain of traction may not be excessive.

4. In determining the maximum speed and the method of traction to be adopted the nature of the banks, with regard to the stability of the slopes, must be taken into account.

5. Along special portions, where traction by horses is difficult but supervision is easy, mechanical traction is still more advisable than elsewhere. Ordinary or electrical towage and rope haulage have given very good results, and each of these systems can be adopted, according to the local conditions.

6. Along the general course of a canal a sure and economical source of motion must be placed at the disposal of all the boats for an undefined distance, and always available for the boatman without being invariably attached to the boat. Boats having on board their motive force can, however, be employed for regular services possessing an assured traffic, with rapid loading and discharging.

7. The traveling cable has furnished good results in its application to two special lengths. It is to be hoped that its application, as announced to take place soon on a large scale along 19 miles of the canal, from Dortmund to the Ems, will enable a definite judgment to be formed of the practical value of the system on the ordinary course of the canal.

8. Electrical towage singly on the Bovet system has been the subject of an interesting experiment. It is desirable that it should be experimented upon on a larger scale to ascertain its economic value.

9. Electrical haulage on the Galliot-Denèfle system after prolonged trials which have proved the practicability of its working from a technical point of view, is at the present time being applied on a large scale, which will enable its practical and economic value to be determined.

Summing up, the second section states that since The Hague congress the mechanical traction of boats on inland canals has formed the subject of varied and interesting investigations, and that new systems have been, or are about to be, tried on a large scale.

But inasmuch as the estimation of the technical and economic value of the processes examined or submitted to experiment demands the careful examination of a collection of data and of complex special and local circumstances, the second section is of opinion that before arriving at definite conclusions on the relative value of each of the systems of mechanical traction investigated up to the present time it is indispensable to await the results of the experiments in progress or about to be undertaken.

Consequently the second section expresses the hope—

(1) That the proper authorities will offer every encouragement to trials, on a large scale, of the methods of mechanical traction which may appear to them capable of affording the best practical results.

(2) That detailed and comparable returns of the experiments on the mechanical traction of boats on inland canals will be presented at the next congress, drawn up in accordance with a programme clearly laid down by the organizing committee.

Second question: Single lock gates.

1. Lock gates which are lowered down present the essential advantages of single gates. They are expedient for the upper gates and for protecting gates. They are inexpedient for the lower gates, owing to their great height and the difficulty of inspecting parts always under water.

2. Rolling gates reduce the length of the side walls; but, on the other hand, they necessitate the construction of a special gate chamber. They appear to be suitable for closing very wide locks and where the fall is very large and variable.

3. Lifting gates possess the general advantages of single gates and afford the same economy of masonry as rolling gates. On the other hand, however, they require cumbrous and costly machinery for working. It is well to restrict them to canal lifts and discharging sluices.

4. Single gates turning on a pivot claim the attention of engineers. Notwithstanding the lengthening of the lock which they involve, they are not more expensive than mitered gates. They are subject to less strain, cause less loss of water, are more easily adjusted, repaired, and replaced, and their working is simpler and more regular. Nevertheless the great expenditure of water and the increase in the period of locking, resulting from the lengthening of the chamber, are inconveniences which, as regards the lower gates, may in certain cases counterbalance and even outweigh the advantages mentioned above.

5. The choice of system of single gates does not necessarily imply the installation of mechanical appliances. These gates can be worked by hand by one man alone, without undue strain and within a period quite allowable in practice.

The mechanical appliances for working, actuated by water under pressure, by electricity, or by turbine, and transmitted by gearing, are justifiable on canals with a large traffic, and the services they render are far from being disproportionate to their relatively high cost.

The discussions have led the section to express the hope that the programme of questions for the next congress will include a comparison between metal gates and wooden gates, as regards their initial cost, the cost of maintenance, their durability, and the facility of repairs and operation.

Third question: Means of securing the impermeability of the bottom and sides of a canal.

1. The impermeability of the bed and banks of a canal has more especially to be considered in the design and execution of the works.

2. On existing canals the choice between the various methods of stopping leakages depends essentially upon local conditions, particularly the height of the banks, the nature of the strata traversed, and the navigation level compared with the level of the subterranean waters or of floods.

3. When an abundant supply of water is available, and there is no immediate necessity to make the bed of the canal water-tight, the deposition of silt may give good results if the fissures in the permeable soil are of small size.

4. Puddle constitutes a very efficient means of stopping leakages in embankments and in cases where the soil is subject to settlement. It is generally cheaper than concrete work and is very suitable for stopping local leaks, particularly in the form of trenches made in the banks. Under the same conditions compression may equally conduce to impermeability.

5. Concrete work gives very good results when laid upon incompressible soil and when suitably protected.

6. A 6-inch layer may be regarded as a minimum thickness for concrete work.

7. A surface coating may be omitted without inconvenience, provided it is used at special places. Generally it suffices to smooth the mortar well at the surface of the concrete.

8. Coating over the concrete layer with coal tar is very serviceable for securing impermeability.

9. In reaches subjected to periodical under pressure, whatever method may be adopted for stanching leaks, it may be expedient to counteract the effects of these under pressures by some arrangement for insuring the flowing away of the underground water.

Fourth question. Mechanical raising from reach to reach of water supplying a canal.

The report presented by Mr. Rudolph proves that the mechanical lifting of the water supply of a canal from reach to reach forms the subject of important investigations.

Moreover, the report drawn up by Mr. Galliot shows that the provisional installations provided in France, on the Briare and Center canals, and the installations definitely set up on the Burgundy Canal for raising the water from reach to reach have given relatively advantageous results in practice.

In the present state of the subject, however, no precise conclusions can as yet be arrived at on the question submitted.

The section is of opinion that the application of electric energy to the supply of water to canals, by the mechanical lifting of the water from reach to reach, may give advantageous results in certain cases, notably when the installations developing the energy and transmitting it to a distance can be used at the same time for supplying water to the canal for the mechanical traction of the boats, as well as for working the locks and the appliances on the quays, and for lighting the waterway.

The second section expresses the hope that the continued investigation into the supply of water to canals, by mechanically raising the water from reach to reach, will be placed on the programme of the next Congress.

THIRD SECTION.—*Tidal rivers and ship canals.*

First question: Formulæ of the characteristics of a tidal river.

Formulæ.—Name of the river. Concise geographical description. Indication of the important tributaries discharging into the tidal portion. Definition of the outlet.

N. B.—The portion in italics denotes the data which are considered of the greatest importance; the others indicate useful information, but less essential.

FIRST PART.—*Régime of the sea near outlet.*

1. Hydrographic chart. Cotidal lines.
2. Sea currents.
3. Tidal diagrams, of equinoctial spring tides, of average spring tides, of average neap tides. The manner in which the averages are determined should be indicated.
4. Prevailing winds and storms. Their influence on the tides. Diagrams showing the prevalence of the winds. Height of the waves during storms.
5. Nature of the sea (bottom outside the mouth) and of the adjacent coasts. Transport of materials; bars; their changes.

SECOND PART.—*Régime of the river above its tidal limit.*

1. Fresh-water discharge of the river and of its tributaries at the low stage; during ordinary floods; during very high floods; mean discharge. Periods and prevalence of floods. (The gauging stations and the manner in which the mean discharge has been obtained should be indicated.) Monthly diagrams of the mean, maxima, and minima discharges. Curves of the discharges as functions of the water levels.
2. Materials carried down by the river; their amount; their nature.

THIRD PART.—*Régime of the tidal portion.*

1. Plans with lines of soundings. (Decimal scales; the datum to which the soundings are referred to be stated.)
2. Longitudinal sections. Section along a line marked on the plan showing: (*a*) The lines of high and low water for the tides stated in the third paragraph of the first part, and with a mean fresh-water discharge; (*b*) instantaneous tidal lines every hour; (*c*) the limits of the propagation of the flood tides. Similar particulars for the periods of low stage and large ordinary flood. Indications of variations in the bed, either natural or resulting from works. Heights of the banks. Highest water levels.
3. Cross sections with their lines marked on the plans—changes.
4. Local tide diagrams at the states of tide given and with a mean

fresh-water discharge (the distances between the axes in the abscissæ being made equal, according to the scale, to the distances between the stations, and the hours corresponding). Curves of the velocities of propagation of low water and high water.

5. Diagram of the wetted sections below mean low water and between mean low water and high water (the distances of the stations being the abscissæ), and of the volumes introduced at various places on the river (indicating the state of the tide and the fresh-water discharge corresponding to each diagram).

6. Diagrams, for the stations given in 5, of the discharges and mean velocities per second deduced from the calculations of the particulars of 5, the distances between the stations being the abscissæ and of the corresponding wetted sections. Diagrams of the mean velocities as functions of the water levels.

7. Velocities observed at various stations, in various points of the section and at different heights, especially in the lower portion of the river.

8. Information as to the nature and amounts of the materials carried down.

9. Indications as to the changes in the banks and channels.

10. Saltness of the water.

11. Works executed; their results.

Second question: Modes of estimating the cube of tidal volumes.

The congress is of the opinion that it is unnecessary to come to a decision on the relative value of the methods employed for calculating the tidal volumes, since the choice depends essentially upon the amount of precision required by the engineer in each case.

Nevertheless, considering that the work occupies a very long time, which can not be spared by the engineer, the congress considers it desirable that the methods adopted should be simple enough to be understood and worked out by his assistants.

Whatever may be the method employed, it is desirable that the section made use of in each operation should always be taken at the same places, in order to render the results obtained at different periods more comparable.

Third question: Means of consolidation of ship-canal banks.

The congress considers that in canals traversed by seagoing vessels at a considerable speed, and also possessing a large inland traffic, it is expedient to protect the banks sufficiently to enable ships to navigate the canal at the highest speed compatible with the relation between their largest cross section below the water level and the water section of the canal.

Among the different systems employed or proposed for the protection of the canal banks the preference should be given to stone pitching, carried down to a sufficient depth. Nevertheless, in certain special

cases a vertical protection, especially timber sheeting, can be advantageously employed.

Fourth question: Dredging.

Suction dredgers possess a notable superiority in economy in soils which can be readily put in suspension. When the dredged material does not settle down quickly these dredgers can not be advantageously employed unless the material can be deposited by pumping it through pipes. This type of dredger, moreover, is capable of working in a greater amount of swell than other dredgers. The contrivances employed or proposed for disintegrating compact materials so as to render them capable of being pumped up are worthy of being investigated with the greatest care; but the method has not yet been sufficiently employed to enable the congress to decide upon its value.

Bucket-ladder dredgers can work in almost any kind of material, but they are specially applicable to compact, hard, and variable strata. They are consequently serviceable in a number of instances concurrently with large single, clam-shell, and bucket dredgers.

These last types of dredgers have not yet formed the subject of any reports presented to navigation congresses, and it would therefore be desirable that they should be among the questions to be considered by the next congress, as dredging always forms a part of the deliberations of these congresses.

The congress expresses the hope that in the future reports engineers will take special care to define exactly the conditions under which the quantities have been dredged, and the cost determined, in order to render the particulars about these as comparable as possible.

FOURTH SECTION.—*Seaports.*

First question: Warehouses and sheds.

Considering the preponderating influence which variable elements in the different ports, especially the nature of the traffic and the commercial customs, must have on the conditions of the establishment of quays and warehouses.

The fourth section is of the opinion that there is no occasion to draw up general rules with regard to these conditions of establishment, as the arrangements adopted in each particular case are of interest solely by way of indication for analogous cases.

Second question: Relative surfaces of the different parts of a seaport.

The fourth section proposes that the following question be put among the list of subjects to be considered by the next congress:

To seek by the nature of the traffic, both special and general traffic, the possible utilization of the installation, for this purpose, of the ports; to give the diagram of the variations in the extent of the traffic and to deduce from it rules enabling the dimensions of the different parts of a port to be determined when its probable traffic is known,

and to regulate the extension of existing ports when the probable development of the various branches of commerce is known.

Third question: Free ports.

Conclusions.—As a free port owes its origin to the economic régime adopted, the fourth section considers that there is no reason for the congress to pass any resolution on this subject.

On account, however, of the influence which the same régime might have, according to the details of its application, on the commercial activity of a port, and on the rapidity of the operations of loading and discharging which are carried on there, the section thinks that the study of the question might be continued under the following form:

Means employed for securing, developing, or facilitating, with a given commercial régime, the commercial operations in seaports.

Fourth question: Single lock gates.

Single gates (such as rolling caissons) offer in general important advantages in sea locks.

FIFTH SECTION.—*Tolls, dues, and local charges.*

First question: Maritime tolls and local rates. Mode of collections.

When the levying of tolls in a seaport has been decided upon, it is advisable to frame these tolls, both as regards their assessment and their amount, on as varied a scale as possible, so as to secure for them the maximum flexibility.

It is especially useful to include in the assessment of the tolls the dimensions of the vessel, the proportion of its load, the nature and importance of the operations carried out by it in the port, the length of stay which it makes, and the position it occupies there. The price can be graduated according to the class of the navigation and the nature of the merchandise. The authority intrusted with the administration of the tolls can, under these conditions, apply them in the manner most appropriate to the different commercial conditions of the port.

Second question: Unification of the gauging system of inland boats.

The fifth section declares that the reform elaborated by the international conference of Brussels of 1896, with reference to the navigable waterways of Germany, Belgium, France, and the Netherlands, is of great interest in every respect. It expresses the hope that the regulations to be introduced for carrying this reform into effect may be settled and put in force with as little delay as possible.

The section trusts that the States of central and eastern Europe will come to an agreement as to the basis of a system of uniform measurement of boats for inland navigation.

In accordance with these views, it is desirable that future agreements shall approximate as nearly as possible to the agreements adopted by the western States.

At the final general meeting of the congress it was voted to hold the next congress at Paris, in 1900.

At that meeting it was also voted to form a permanent organization at the Paris congress.

The bureau of the present congress, composed of the Belgian organization committee and the vice-presidents of the congress, was constituted a committee to consider the whole subject and report to the Paris congress. To this committee were added several members who had taken a leading part in the organization of previous congresses, and the committee was authorized to add others to its membership.

Closing this introductory report, and pending the completion and submission of the résumé of papers and discussions,

I am, sir, yours, respectfully,

E. L. CORTHELL, *Civil Engineer*,
Delegate of the State Department, United States Government, to the Seventh International Congress of Navigation.

Hon. JOHN HAY,
Secretary of State, Washington, D. C.

CHAPTER II.

RÉSUMÉ OF REPORTS.

FIRST SECTION—CANALIZED RIVERS.

First question.—Raising of existing weirs—Means to be employed for executing the work in order to delay navigation as little as possible, and to reduce the cost of the work.

PAPER BY MR. E. FENDIUS, OF BELGIUM.

The raising of a barrage or weir may be required for the special reason of improving the navigation by a combination of conditions inherent in the navigation or in the river itself.

The canalization of the River Meuse in Belgium has now a minimum depth of 2.10 meters (6.89 feet) and is capable of accommodating vessels of a draft of 1.80 meters (5.9 feet).

Apart from the maintenance of ruling depth the general interests of navigation require that lowering or raising the barrages should be done as nearly at the same time as possible. This can not always be done at once, for the rise in the river may be confined to a local section of it; sometimes a flood of lesser importance will require the barrages to be lowered, as for instance, below Namur, where it is often necessary to maneuver the weirs. Also the fall of the canal or river levels is very variable. Above Namur the slope is 0.453 meters per kilometer (1.48 feet) while below it is 0.282 meter (0.92 foot).

The object of raising the height of the weirs of the Lower Meuse is to reduce during ordinary floods the frequency of lowering the weirs and of bringing all the canalization work as much as possible in time of flood to the same régime.

A practical solution of these conditions will have the effect of reducing the choking up or stopping of navigation on account of flood, of diminishing the risks of accidents, and of decreasing the troubles caused by so many maneuvers of the barrages.

After describing the method which he proposes for raising the level of the weirs at the cannon foundry at Liege, the author concludes that the general raising of all the weirs can best be done by iron caissons, doing the work section by section, and as the only method of safe-

guarding the interests of navigation, and that the experiment thus tried there would furnish sure indications of how the work could best be done at the other barrages of this part of the Meuse. (See Plate I (No. 1).)

PAPER BY MR. G. PAVIE, OF PARIS.

In 1879 M. de Freycinet, then minister of public works of France, submitted to Parliament a scheme for unifying all the waterways of France, which had hitherto slowly developed without any regular plan or uniformity of size. The purpose was to do what the railroads had done—establish systems, where, without breaking cargo, the products could be transported from their place of origin to their place of destination to be used in the industries of the country.

The work under this law of 1879 divided the country up into principal and secondary systems—rivers, canalized rivers, and canals.

A minimum depth was fixed which permitted a boat to traverse the entire system, or network of navigable ways, with the maximum load which it would carry. This project has gone on developing even up to the present time.

It has therefore been necessary to resort often to the work embraced in the first question of this section, viz, the raising of existing barrages or weirs.

The writer does not propose to take up the question of extensive and expensive and elegant constructions like those on the Lower Seine, but to treat of the simple transformation of an existing weir, where the raising of the surface is less than a meter (3.28 feet), or about 0.60 meter (1.97 feet). The raising in the Seine, above referred to, was from a depth of 2 meters to 3.20 meters (10.50 feet). This moderate raising of the surface is about all that is generally permitted, on account of the low level of the banks and the danger of flooding wide river bottoms of rich cultivated land. This transformation often requires, especially in the east of France, the suppression of the old barrages of a low level, as it is impossible to raise them without interfering with the easy discharge of the floods and it is unwise to attempt to build upon their foundations the necessary machinery for handling the movable dams.

The discussion will be limited, therefore, to the Seine above Paris and the canalized Marne, where the transformation conforms as nearly as possible to the question under discussion.

The types used for raising the weirs are two only, the "Chanoine bearers" and the "Poirée trusses," the works on the Marne being specially discussed, because those on the Seine have been published in very interesting memoirs in the Annales des Ponts et Chaussées by the chief engineer, M. Lavollée. On the other hand, on the Marne will be found a very ingenious system not generally known in respect to some

of its features. It will be more useful to examine and criticise works the inconveniences or value of which have been known than to endeavor to establish general rules difficult to lay down for conditions so complicated and variable.

When it is necessary to simply raise a weir and its water level, one must first ascertain if the masonry and other parts will be able to withstand the new pressures and to resist the tendency to pull the masonry apart, caused by the greater pull and workings of the apparatus under the most favorable conditions. The raising should not be attempted until it is absolutely certain that the work is strong enough to resist the new strains. If it is a question of simply replacing the low Chanoine bearers (hausses) by higher ones the operation is quite simple, but even then it is necessary to change all the movable parts of the work.

On the Upper Seine, in the navigable passes, the operation consisted in substituting for the old bearers of 3 meters (9.84 feet) in height new bearers of 3.40 meters (11.15 feet), and replacing at the same time the trusses and buttresses. The work was done without delay to navigation by means of a movable panel, described by M. Lavollée in the Annales des Ponts et Chaussées, 1883, first session. Four hundred and sixty new bearers were then put in place, at the rate of 2 each day, at an expense of about 830 francs ($166) per bearer, and the expense of putting it in place 35 francs ($7).

The work on the wasteweirs, where there was a footway, was more troublesome, as the masonry was not first class. Some of the work was done by caissons with compressed air, which M. Lavollée described in the Ponts et Chaussées Annales, 1884, second session. The writer leaves this subject with this reference.

He then discusses various alternative methods in considerable detail, and gives some sketches in the appendix of the manner of doing the work on the Marne, to which reference must be made to understand the plan and details. (See Plate (No. 2).)

PAPER BY MR. E. ROLOFF, OF OPPELN, GERMANY.

In the strife between waterways and railways, it has been found absolutely necessary to increase the size of the boats, and consequently the depth of channels; but as dredging is too costly and gives uncertain results, the additional depth can almost always be obtained by raising the existing weirs.

Provisional raising of the level.—As, for example, where the bed of the river has silted up. In needle barrages this is possible when the rise required is not too great, for the needles come up usually to the height of the footway; that is to say, 0.40 meter (1.31 feet) above the

ordinary or normal water level. The strain upon the various parts would not likely pass the limits of safety, and the damage to the river land would not be great.

Permanent raising of the level.—Two objects should be kept in view: First, to do the work with the least possible expense, and, second, with as little hindrance to navigation as possible. The work embraces changes in the barrages, the locks, and the works upon the banks.

Transformation of the barrages.—There is no general rule to adopt; each case must have its own solution; even upon the same river one can not employ the same means in all cases. To reduce to a minimum the expenses of the work, the foundations and piers of the barrage should not be disturbed, only the movable parts, and here the question arises if the height of the level permits the employment of needles. The determining element in this case is the weight of the needles, which in rivers of varying volumes and frequent maneuvers ought not to weigh more than 40 kilograms (88 pounds). With needles in wood, the height is already reached, and is between 2 and 2.50 meters (6.5 to 8.2 feet), and for the height of the water above the sill of the barrage of 3.75 meters (12.30 feet), but this limit can be exceeded with needles formed of tubes of wrought iron. If it follows that a barrage with needles is not to be recommended, then resort should be made to movable trusses (fermettes) with flood gates (vannes), such as has been placed on the Lower Seine. In a barrage with needles one of the constructive elements of the first importance is to see that the supports or trusses are well anchored into the foundation of the work, so that they will not be overturned by the pressure of the water. The renewal of such an anchorage will not give results absolutely certain; generally the fermettes must be widened at the base.

To illustrate, it is assumed that on the canalized Oder the present minimum depth of 1.50 meters (4.92 feet) be increased to 2.50 meters (8.2 feet).

Plate I (No. 3) represents a barrage, or weir, of this section of river, presenting mean dimensions. It is composed of two wasteweirs of 35.20 meters each (115.49 feet) of free opening and a navigable pass with 25 meters (82 feet) of free opening, of which the sill is placed 0.50 meter (1.64 feet) below that of the wasteweirs of the barrage. The levels of the water after raising the work and modification of the dam are indicated in broken lines. In the two wasteweirs the raising of the work gives upon the sill a depth of water of 3.60 meters (11.8 feet). As the volume of water is very variable, the needles had to have a length of 4.58 meters (15.02 feet) and a thickness of 0.14 meter (0.46 foot). The weights of these needles are thus about 42 kilograms (92.59 pounds). These dimensions are considered admissible.

The anchorages above the trusses of the barrage extend to under-

neath the dressed stone; the weight of the masonry resting upon each anchorage is about 3,000 kilograms (6,600 pounds). In reference to the shocks and vibrations which affect the frames, the strain upon the anchorage can not, however, exceed two-thirds of this weight. Consequently one does not have to take account of the resistance of the masonry to shearing. A calculation based on this hypothesis gives for the new frame a width at the base of 2.75 meters (9.02 feet). The support below can be placed upon a new-cut stone, to be placed not far below the existing block. Under these conditions the foundations of the barrage, 6 meters (19.68 feet) wide and consolidated by the anchorages, still offers a sufficient resistance. In the navigable pass in order to raise the work by the employment of needles they should have a length of 5.09 meters (16.69 feet) and a thickness of 16 centimeters (6.30 inches). The weight of these needles is about 32 kilograms (70.4 pounds). The employment of needles as heavy as these not only renders the working of the barrage more difficult, but it also increases the expense of maintenance. Under these conditions it is not thought best to recommend the use of needles.

The upper sills, which in this system are covered when the barrage is down, ought to have sufficient weight to make the maneuver easy and sure.

It is recommended in such a case as this to replace needles by sluice valves and to modify the plan of the frames accordingly. The anchorages of the frames in the navigable pass may have to withstand a strain of 3,500 kilograms (7,700 pounds), and they should have a width of base of 3.75 meters (12.30 feet). The foundation of the navigable pass has a width of 16 meters (52.48 feet).

Outside of placing the new-cut stone for the downstream support of the frames and in changing them, the works comprise principally the enlargement of the hollow quoins in the piers for the enlarged frames and the raising of the piers. These works would not present any difficulty.

In consequence of employment of larger frames and of sluice valves or gates in place of needles in the navigable pass, it will take more time to lower the barrage on the arrival of a rapid summer flood. This inconvenience is not, however, very great, for, thanks to the greater height of the footway above, the employees can easily lower the frames.

In case the width of the existing foundation is not sufficient to receive the new downstream support of the frames it will be necessary to increase the width of foundations. It will be necessary then to place a row of sheet piling a certain distance from the barrage to enlarge the foundations and to place a new support upon this enlargement. This work will, however, be done under great difficulty, for the placing of a new row of sheet piles in the bed of the river below the barrage

will require the consolidation of the ground in such a situation as to make it very costly; besides, it is difficult to establish a good bond, which is indispensable, between the new and the old part of the foundation. This work is therefore uncertain of good results and is not recommended except in special conditions.

When the width of the sluiceways is not too great and when the construction of piers in the openings of the barrage is possible without reducing too much the width of the river, the sluiceways can, after the suitable raising of the piers, be provided with fixed bridges which serve as points of support for the machinery of the barrage. In this way a work can be built similar to the barrage which has been placed upon the Elbe at Pretzien, not far from Magdeburg. The dimensions of the barrage and the height of the water will determine the question whether to use needles, or sluice valves, or venetian blinds, and if the supports should be constructed by the aid of shut profiles or frames in the form of trellised trusses, or, finally, if the raising of these supports, which would be necessary only in times of breaking up of the ice, should be operated by lowering upon the ground or by raising around the trusses of the bridge.

When the supports and the anchorages existing in the foundation of the barrage and serving for the point of support of the old frame can not be utilized for the new installation without important changes, the cut stone should, however, always give the means of installing new supports.

One disadvantage of this mode of construction, having reference to the height of floods and the necessary free height above the height of navigable waters, is the necessity of placing the upper works at a great height above the normal level of the water. This leads to great expense in construction.

In the case of sailing navigation on a river it is necessary that the masts of the boats be lowered.

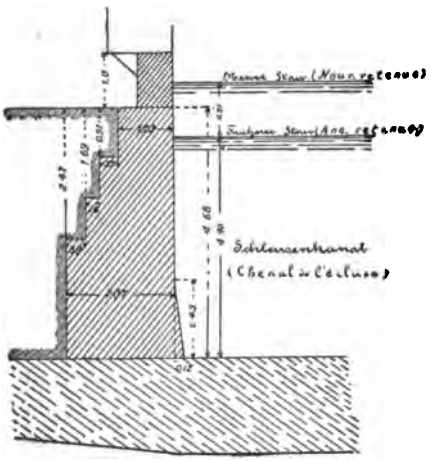
Execution of the work of the barrage.—The works should be carried on, wherever it is possible, without interfering with navigation. It will often happen, as in the case of the canalized Meuse, that one can by the use of complete dams place the foundation of the barrage in the dry without changing very much the level of the navigable water, and the works can be executed in the excavation. If such an arrangement of the work can not be made, then it should be carried on by the aid of open caissons. These may be placed on the foundations of the barrage and the water pumped out, so that the masonry can be rebuilt and the new stone work properly placed, as well as the supports.

In order to change the frames, when this work can not be done in the winter season, when there is no navigation, divers can be employed, as is done during navigation when the frames are damaged and need to be repaired.

When the conditions are such that the above methods are not possi-

ble, it will be necessary to make a new construction placed in the vicinity of the old work and as near to it as possible and above the old barrage. To place it below would entail very considerable difficulty and large expense.

Changes in the locks.—The locks in barrages must also, in most cases, be modified, and these modifications consist in the first place of raising the inside walls and the earth about them to the new height. This can be done by the aid of a masonry wall, as indicated in the accompanying sketch.



This wall carries the footway of the enlarged lock, if necessary, by an overhang. The remaining important modification of the lock is the raising of the heads of the gates. It is clear that all these works and the renewing of the anchorages of the gates can be executed without great inconvenience to the navigation, part of the work to be done during the navigation period and part during the winter season.

Effect of the raising of the water level upon the banks.—If the banks are high, the raising of the level of the water has no special effect upon them, but if on the contrary the river is bordered by extended low banks, as is often the case in the north of Germany, it is necessary to raise these banks in order to avoid an inundation of the rich cultivated lands. It is also necessary to take care of the filtration of the water, which is done by drainage ditches, which conduct the rain water as well as the filtrated water to the next level below. In spite of these measures it is true that the raising of the level of the water often interferes seriously with the agriculture of the adjoining lands and often these disadvantages attain such importance as to more than counterbalance the advantages to navigation by the raising of the water level.

The writer, as an illustration from an actual work, describes the raising of the barrage of the River Oder at Oppeln in 1892–1894. The conditions were such that the situation of the old works did not permit

their employment to make the new elevation, and at the same time the existing barrage could not be transformed. The plan and profile of the works before and after reconstruction are seen on Plan II (No.4). An examination of the plan will show that the Oder is separated at Oppeln into three arms, the Winske, the old Mill Race, Muhlgraben, serving for a winter haven, and the principal arm of the Oder, which passes between the other two. Up to 1892 there was in the Oder a wasteweir built of wood with a sluice of 16 meters (52.48 feet) in width, which was shut by means of a curtain of needles. There also existed in the Muhlgraben a wasteweir of masonry shut by a tumbling dam. The heights of these chutes are indicated on the longitudinal profile. There was at that time no lock for navigation, which was made without a lock through the Winske, which was very tortuous and very narrow. At the side of the barrage in the Winske there was a lock, but this did not serve formerly for navigation, but was used exclusively as an entrance into that arm of the river for the purpose of a winter haven or for discharging freight. The exit from this part toward the Oder was not often passable except for empty boats, for in the neighborhood of the bifurcation of the Winske and the Oder there was not ordinarily found a sufficient depth of water.

As the canalization of the Oder, both above and below Oppeln, was carried on so as to obtain 1.50 meters (4.92 feet) at the lowest water and suitable for boats of 8.20 meters (26.89 feet) beam and 55 meters (180.4 feet) length, it was necessary to radically change the dimensions of the river at Oppeln. The Winske could not conveniently accommodate boats of these dimensions, therefore the navigation had to be arranged for in the Oder itself. It was indispensable to begin with a raising of the level for a distance of about 6 kilometers (3.7 miles). It would have been very expensive to have resorted to deepening, which was rendered particularly difficult by the presence of calcareous rock in the bed of the river. This raising of the river level was fixed at 0.84 meter (2.75 feet) above the existing mean level of the water. This was sufficient for the needs of navigation and did not inconveniently disturb the low lands of the banks. These works were performed as follows:

First. In the Muhlgraben, at the bifurcation of this branch and the Oder, a new barrage was built with fixed posts and a framework with sluice gates of 32.40 meters (106.27 feet) clear opening. The old barrage near the lock in the Muhlgraben preserves the former height of water, while the new barrage, with sluice valves, raises the level of the water to 0.84 meter (2.75 feet), and this new barrage has changed the Muhlgraben into a winter haven absolutely sure against the ice.

For protecting the barrage itself against the ice, the four ice breakers existing at the entrance of the Muhlgraben have been restored by adding a row of three new ice breakers.

Second. In the principal arm of the Oder the old waste weir could not be utilized for raising the level of the water. A location for the new work was found just below the old barrage, but beyond the downstream foundation of this work, which proved to be the most advantageous. The new work consisted of a barrage of needles, near which was placed the new lock. The barrage has two openings of 42.20 meters (138.458 feet) each and one of 20 meters (65.6 feet), which gives in all 104.40 meters (342.53 feet) of clear width.

Third. There also had to be placed in the Winske a dam located at the point where this branch leaves the main Oder. This consists of a fixed waste weir of masonry of 36 meters (118.08 feet) of clear width, the crest of which is at the level of the new elevation.

The works were conducted as follows: During the year 1892 the barrage with sluice gates was built in the Muhlgraben, the foundation of which was placed directly on a rock bed.

In the autumn of 1892 and during the year 1893 the barrage and lock were built in the Oder. The foundation consisted of sand and gravel, so that the barrage was built between rows of sheet piling. During this time the navigation was turned, as formerly, through the Winske.

During the year 1894 the barrage of the Winske was constructed and the navigation used the new lock. It was necessary to hold back the navigation for two days only, at which time a guard dike of fascines was placed at the head of the Winske, in the protection of which the barrage was built; after which it was possible to raise the level of the water of the Oder and reestablish navigation.

The cost of these works is as follows:

	Francs.	Dollars.
Barrage with sluice gates in the Mulgraben	80,000	16,000
Barrage of the Oder	185,000	37,000
Adjoining lock	278,000	55,600
Winske barrage	45,000	9,000
Earthworks, protection of banks, demolition of the old barrage, etc	157,000	31,400
Total	745,000	149,000

PAPER BY MR. E. D. MARTEN, OF ENGLAND.

Raising of existing weirs contrasted with dredging as a means of obtaining an increase of navigable depths of channel.

The paper is confined to the conditions of the river Severn, in England, which the writer has had charge of, either by himself or with his father, for twenty years.

This river is canalized from Gloucester to Stourport, 46 miles, the water being upheld by a series of 6 weirs in the main stream.

Prior to 1890 they gave a minimum depth everywhere at low summer level of 6 feet, with many intermediate pools of 10 feet or more, so that by removing intervening shoals the navigation was capable of great improvement by a comparatively small outlay.

In 1889 a survey and report was made upon securing a 10-foot navigation for 30 miles, and 7 feet for the remaining 12 miles near Stourport.

The estimate was £30,000, £20,000 of which was for dredging and the deepening of locks, nearly the whole of which might have been saved by raising the level of three of the weirs about 3 feet each and of the remaining weirs not more than 1 foot each. Consequently the advisability of doing this latter work was considered with great care.

There were three leading features of the problem:

First. The question of cost of raising the weirs as compared with £20,000 required for dredging.

Second. The doubt as to whether Parliament would sanction an opposed scheme for raising the level of the weirs when it could be shown that for a comparatively small extra outlay the same object could be obtained by deepening.

Third. The interference of the clear headway under the bridges by raising the level of the water.

As to the raising of the weirs it was found there need be no serious engineering difficulty. They consisted of two rows of sheet piling driven obliquely across the river parallel to one another and from 20 to 30 feet apart and at different heights, the upper at the proposed and the lower at the original summer level. The space between was filled with large rubblestone, forming the apron of the weir. These dams could have been easily raised by an additional timber bracing and sheeting, the cost of which, by careful estimates, would not exceed £12,000, a large saving over the proposed dredging. A further advantage was that if the weirs were raised the channel would extend the whole width of the river, 200 to 300 feet, while the estimates for dredging provided for a channel of only 40 feet wide; but the plan was abandoned on three grounds.

First. Because it reduced the headway under the bridges materially.

Second. It raised the line of saturation over many miles of alluvial land adjoining the river.

Third. Because of the probable opposition on the ground that the raising of the weirs would increase the liability of floods.

These points are discussed in detail by the writer. The work was finally done by dredging and was completed about three years ago. One of the most interesting results has been the marked increase in the flood discharging power of the river, which is a strong argument in favor of deepening in this case, as compared with weir raising, and which the writer thinks "should always be borne in mind when any future scheme is under consideration."

The measure of amelioration has been carefully ascertained from the daily reports of the height of water, which are kept at 8 successive stages throughout the navigation. The diagram (No. 5) shows the lines of floods before the river was deepened and afterwards. That before the improvement shown by full lines; that subsequently by a broken line. This diagram explains itself.

The dredging in every case was for the purpose of deepening over shallows; in other words, enlarging the sectional area where contracted to less than the normal section.

The writer contends that a contracted sectional area has precisely the same effect as a weir, requiring an extra head to overcome the obstruction offered to the flow of water. This principle is illustrated in detail by an assumed case.

In the actual case of the Severn, the contractions, which the author shows create level pools, were numerous and their influence continuous, and the diagram shows that the effect of their removal was accumulative, becoming more marked the higher up the river it is noted, so that at Stourport, at the upper end of the slope, the gain has been in one flood almost 4½ feet. The views of the writer, resulting from his experience upon the Severn, are as follows:

In conclusion, and as a result of the investigation and considerations detailed above, the writer is strongly of the opinion that where fixed weirs are concerned the proper method of obtaining an increase in navigable depth is, as a general rule, to be found in dredging, and not in the raising of the weirs.

Where movable weirs exist it is possible that raising their level might, in certain circumstances, be preferable to dredging, but it would be exceedingly costly, and would almost inevitably lead to friction with riparian interests, while the advantages of increased flood discharge resulting from dredging would be altogether lost.

The writer is in no respect an advocate for dredging as a *substitute* for weirs—a system which usually results in nothing but a waste of money. It is only when the pool has once been created by the erection of a weir that dredging in an inland stream can be adopted with advantage.

Second question.—Consolidation of weir foundations. Works intended to prevent the water from passing underneath the foundations, so as to reduce the cost of maintenance of works; means of execution to be employed in order to delay navigation as little as possible.

PAPER BY MR. E. FENDIUS, OF BELGIUM.

Consolidation works, which the barrages of a canalized river sometimes require, at once raise the question of deciding upon the most rational plan for the foundations of these works, as much in respect to the form, the dimensions, and the nature of the masonry as to the works necessary to secure the preservation.

Generalized in these terms, the study of the rational form of a foundation does not lead to any one solution of the question. If, on the

one hand, this study refers to the often complex question of the system of foundation which belongs to works, it must, on the other hand, be considered from the special point of view of giving a guarantee of permanence and of operation, which any work should have which often finds itself under a variable fall of water and exposed periodically to the destructive action of floods and ice. When, under the action of a violent current, the foundation of a barrage is more or less undermined, the excavations resulting from these destructive effects lead to filtrations and scour under the foundations and compromise the base of the work. The profiles and dimensions which properly belong to the foundations of a barrage depend, then, in a large measure, upon the nature, the consistency, and the permeability of the subsoil.

Consequently the study of the geological constitution of the soil and the results of soundings taken at places properly chosen will furnish generally the indisputable data in the elaboration of a barrage project.

The writer examines the above questions only from the point of view of the canalized Meuse, which offers good illustrations of the subject in hand. A detail description is given of the geology of the valley of the Meuse so far as it affects the question of navigation. Briefly, there is everywhere at a variable depth a bed-rock foundation; upon it at the surface, first, a vegetable earth about half a meter thick, resting on a bed of mud, the upper part somewhat sandy, suitable for the manufacture of bricks, and the lower part stiffer and of a different shade; below the mud a thin bed of mud and sand embedded with pebbles and very permeable. The proportion of pebbles and gravel increases as the material approaches the rock; near the rock the gravel mass frequently contains bowlders. The question is whether the foundations ought to be founded on the rock or on the gravel. The character of the material above described makes the results of soundings very uncertain; it is often difficult to reach the rock on account of compact gravel and bowlders.

The above sketch of the material shows the incompressibility of the subsoil of the Meuse, and also the necessary character of foundations which ought to be used, especially in point of view of measures of defence against scour, for while it may be incompressible to foundations, it is scarcely of a nature to resist violent currents and eddies and other movements of the water which are occasioned by falls of water above barrages.

Types of foundations of barrages.—They can be classed in three groups, as follows (see Plate I (No. 6): First group, I–VI, between the French frontier and Riviere. Second group, VII, VIII, and IX, at Riviere, Tailfer, and La Plante. Third group, X–XXIII, below Namur.

The barrages of the first group comprise a navigable pass and a

wasteweir, the sills being respectively 0.60 meter (1.97 feet) below and 0.25 meter (0.82 foot) above low water.

The barrage of the navigable pass is on the needle plan, the wasteweir on the movable-bearer plan.

The barrages of the second group also have a navigable way and a wasteweir, and are constructed entirely according to the type of barrages à hausses (bearers) system Chanoine. In reference to the navigable pass, they are often modified by the substitution of trusses and needles beyond the old bearers. The sills of navigable passes and wasteweirs of this group are fixed respectively at 0.60 meter (1.97 feet) below and 0.65 meter (2.13 feet) above low water.

The barrages of the third group are formed of two navigable passes with a closing machinery and a solid wasteweir (deversoir de superficie) of 200 meters (656 feet) length at Barrages XIX and XX, and 150 meters (492 feet) length at the other barrages.

The barrage of the first group.—The foundations both of the barrage and the wasteweir are inclosed in a cofferdam and lines of piles and sheet piling. The cofferdam, which is of wood, surrounds the upper and lower starlings of the isolated piers and is extended under the pitched slopes. This cofferdam work is very well maintained.

The barrage at Anseremme was completed at the beginning of 1878 and put in service September 20 of the same year. After an ordinary flood, which necessitated the lowering of the dam and which lasted from the 3d to the 25th of November, 1878, a considerable scour was produced below the foundation of the navigable pass, and reached the rock at a distance of 25 meters (82 feet) from the cofferdam. The enrockment resting against the woodwork of the cofferdam was generally carried away. Blocks of stone and the débris of the excavation were found 100 meters (328 feet) below. The same flood produced above the navigable pass, and against the cofferdam, an isolated excavation, in funnel shape, the lowest part of which was below the level of the foundation.

In order to meet these conditions the two excavations were filled up, that below by means of an enrockment of large stones, three-fourths of which being at least one-twentieth cubic meter (1.76 cubic feet) in size, and that above by means of sacks filled with béton. The foundation thus excavated by means of this scour was of fine gravel. The first leaks under the foundation of the navigable pass had made their appearance in 1894, showing themselves by very marked bubbles between the woodwork of the cofferdam and the enrockment at points A, B, and C. (See Plate II (No. 7).)

During the closure of the canal in the month of June, 1895, béton was put in above the cofferdam of the foundation, but in spite of this revetment and the employment of cinders and mats of lead for stopping the leak and for presenting above the foundation an imperme-

able massif of protection and also unerodable, these operations renewed at several times were only temporarily effective.

In August, 1897, the leaks which had been partly stopped returned with all their former activity at points of emergence A 2, B 2, and C 2. (See Plate II (No. 7).) The conditions underneath the work and the lines of leaks were very well defined by using slaked lime, which was put in above the work and allowed to pass through it, coming out below at the points above mentioned. It showed that the central part of the barrage had been undermined in a sort of ravine on the lines shown on the plan. On account of the great expense which would be incurred if a special cofferdam and other such works were built, it was best to make a last attempt by introducing into the lines of the leaks below proper materials for closing them up. These experimental operations, long and laborious, made without lowering the water and by constant examination of their result by use of the lime above mentioned, consisted of the employment of cinders, gravel, and fine and large mats of lead, as well as a fine béton, the mixture of which was modified according to the results obtained during the different phases of the work.

While doing the work, it was necessary to reduce the force of the entering water to prevent the dilution of the mortar, and for this purpose to frequently close up the springs A 2, B 2, C 2 by covering them with mats of lead.

The works for preventing the leaks commenced the 12th of September, 1897, and were finished the following October, resulting satisfactorily, for, a month later, in uncovering the locations of the sources of water, A 2, B 2, C 2, it was found that there was no current.

The wasteweirs.—The foundation of these works and the bed below are subjected during the large part of the year to the entire force of the volume of the river and to the fall of the water at the barrage, which hastens the wearing away of the woodwork and causes a disturbance of the foundations, at least over a certain part below the foundations. These deep excavations, which developed themselves the whole width of the work and as far as 10 meters (32.8 feet) at least below the foundation were filled at once and rammed; but this remedy was only palliative; the excavations reformed. All of this necessitated frequent examinations and reparations, which were done while there was no navigation. On account of the insufficiency of the protection by enrockments, even by blocks of stone well laid, there should be stated a general rule for the protection of foundations, which should be done when the work is built in the reaches above by cross walls of masonry and a cofferdam in cement béton. In the part below a rear foundation should be placed 10 to 15 meters (32.8 to 49.2 feet) long, 1.25 meters (4.1 feet) at least in thickness of ashlar masonry. In the navigable channel a rear foundation should be established at the level of the main foundation which it protects.

Barrages of the third group.—These differ from those of the first group in the arrangement of the seat of the foundation, the wall above not being protected by a row of posts and sheet piles. As indicated on Plate I, fig. 3 (No. 6), the part below the foundation which supports directly the thrust developed by the frames, is founded 2.70 meters (8.86 feet) below the sill, while the massif above is 1.70 meters (5.58 feet) below the same level. On account of the relatively low level of the sills the foundations are generally well preserved, the scour not being produced except in narrow limits, which does not compromise the base of the work. It remains to be stated in reference to barrages in general that it is best to found the massif low enough to sustain itself against scour. In reference to the isolated pier, the foundation of the upper starling requires special attention when the barrage is exposed to dangerous currents, which the pier occasions—whirls of water along the lateral walls of the starling—and exposes the bed to scour at great depth. An important repair work, due to this cause, was required in 1897 at Barrage XV at Huy. The pier of this work had been scoured out along the whole contour of the foundation and the excavation extended to nearly a meter below the foundation, and at one point 1.20 meters (3.94 feet) below the masonry. The excavations were filled up with béton after taking out all the loose material, stones, mud, and débris of masonry which partly filled the excavation. This work was done by divers.

A serious accident, due to scour and to insufficient protection of the foundation on which rested the upper starling of the pier, happened the 23d of December, 1889, at the barrage of Visc, which was constructed in the year 1863–64. Immediately following a sudden rise, and after the barrage had been lowered, the part above the pier in question was sunk by a movement of rotation, and took the oblique position indicated by a dotted contour a, b, c, d, Plate III, profile 1 (No. 8). In order to satisfy the interests of navigation, there were executed in 1890 some provisional works necessary to reestablish the normal height of water in this level. These works comprised particularly a dam drawn around the scoured areas and a shoulder arranged in such a way as to permit the maneuver of the floating apparatus. The dotted line on Plate III (No. 8) shows the general disposition of these works. In 1891 a minute examination was made, by sounding and by divers, of the entire barrage and of the area scoured out of the bed of the river, so as to make the necessary enrockments and place mats of lead against the disturbed parts of the foundations.

The writer describes in detail the methods employed.

Permanent wasteweirs.—Plate I, fig. No. 4 (No. 6), shows the general arrangement of the wasteweirs. The wasteweirs not being subjected to the direct effect of flood currents, and having under normal conditions only a thin flow of water over the crest, and the fall losing itself in the deep water below, resist scour better than the foundation of

even the barrage. It is interesting to note the measures which were taken at two wasteweirs to arrest the leaks, which had been localized in a very restricted space. In 1897 the wasteweirs of Huy required reparation under the work on account of some leaks. An examination by divers disclosed a crevice of 6.70 meters (22 feet) in length and 0.40 meter (1.312 feet) in width. After having stopped at once the course of the water by the ordinary means the béton was rammed into the crevice which protected the foundation. In 1878 a vein of water of considerable size, which was produced at wasteweir XII (Selayn), showed itself by a powerful jet of water. The leak was stopped successfully by béton after a first attempt by means of sacks filled with cinders, which was not successful.

This paper does not treat of all the questions which relate to all the types of foundations as well as the means of stopping leaks and consolidating the foundations of barrages. The paper has no other purpose than to relate certain salient facts to show, in certain cases of scour, the causes of danger and destruction which the designer of a barrage should take into consideration carefully, also the régime of the river and the nature of the country which it traverses.

PAPER BY MR. G. PAVIE, OF PARIS.

Unsuccessfully founded and too often with masonry of lime used under defective conditions, the foundations of old barrages rarely offer the qualities of resistance and impermeability which are sought in our day, and which alone are compatible with the requirements of higher levels of water. The consolidation of these old works is therefore frequently required. Whether it be in repairing the injuries, more or less serious, which an accidental cause brought about, or in raising the level of the barrarge, one needs to remedy the old vices of construction or add to the resistance of the foundation on which must be installed the apparatus for the increased height.

It is, we believe, in accordance with these ideas that the congress will have to examine and discuss the works required for preventing the passage of water into the foundations. The difficulty of the problem rests particularly in the uncertainty in regard to the actual condition of the old work. The designs preserved in the archives show the projected plan well; but it is rare that one finds the changes that the engineer was obliged to make during the progress of construction. One is often astonished, after having demolished or repaired a certain number of these old works, to see that they have resisted during so many years the forces which one would naturally expect would have caused their ruin. Their resistance and their permanence can only be explained by a sort of equilibrium of opposing conditions to which they have been subjected. We had a striking example of this when,

having put in, in the dry, the foundation of a barrarge by means of dry dams, we saw the paving which covered the foundation between the bands of cut stone rise, under the action of the water, through the massif of béton, otherwise perfectly dry, as soon as the head of water passed 2.50 meters (8.2 feet).

If one has to specially increase the strains which the new systems of barrages put upon the foundations, it is necessary, so as not to destroy this equilibrium, to remedy the principal causes of disturbance which one has been able to ascertain. If it is impossible to improve the quality of the masonry, all that can be done in certain cases is to make a more complete connection with the elements of the work, generally formed of stone of good quality.

These works can be carried on easily without interfering with navigation by employing, if necessary, a caisson forming a movable dam, which can be transferred to different parts of the foundation.

It is often impossible to find out the sources of disturbance, of which the cause is often unnecessary. We will cite, apropos of this, a fact which we have known in the reparation of a barrage, where we could not pump the bottom of a ditch surrounded by dry dams and where the black and infected waters thrown out by the pumps could not certainly come from the river. When we had successfully pumped out the ditch, after several days of uninterrupted work and after tripling the pumping force, we had completely dried the large cut of a railroad several kilometers above. In such cases the remedy, to be successful, must be applied as near as possible to the point where the filtration begins, and not, as it is sometimes endeavored to do, at the point of emergence of the leaks. To close the hole there is likely to be produced a new course for the water, on account of the unknown condition of the work, and it consequently would be, perhaps, more disastrous than the inconvenience which one wishes to remedy. The attempt is sometimes made to stop infiltration or to better the conditions of the foundations, as one dries the slopes of a canal by charging the water with cement or diluted clay. This promising proceeding, although it tends to compel the destructive forces to gradually reduce their force, does not inspire us, however, with much confidence.

Sometimes hundreds of cubic meters of clay have been put in above a lock without successfully stopping the filtration, and which menaced the work which was founded on a sandy soil. We have also examined the foundation of a lock in which had been injected, under pressure, some years previously, considerable quantities of diluted clay, and have noticed in the béton of the foundation the holes and pockets which had for a long time caused anxiety, and finally the reason for the reconstruction of the work. We do not dare to say that there was no clay found there, but we can assert that it did not attain the purpose for which it had been used with a great deal of trouble and expense.

If the masonry is really unstable the best thing to do, without doubt, is to reconstruct a new foundation, and it can be done without interfering with the navigation by employing caissons of compressed air in conditions similar to those described by M. Lavollée in a Memoir of the Annales des Ponts et Chaussées, 1884, second session, where will be found many interesting details and possibly a model of ingenious application.

Generally one must content himself on the upper Seine and on the Marne to have recourse to proceedings less complete, but more simple and more economical, which we will briefly review.

The waste weirs of the barrages of the upper Seine, formed of a massif of an inferior béton, founded on gravel, have been for the most part reconstructed since the execution of works for raising the plane of the water. Some have been preserved in their primitive condition by placing trenches of béton for the purpose of arresting the filtration which was produced in the foundation, where the thickness and the width were insufficient and would endanger the solidity of the works.

The author gives instances and describes this method of making safe the foundations of the old works.

PAPER BY MR. E. ROLOFF, OF OPPELN, GERMANY.

Filtration under the foundations of barrages, and the damages which they cause.—Soils composed of sand and gravel, which usually form the beds of rivers, present, with few exceptions, such permeability that, for heights of water from 2 to 3 meters, like those of the barrages of the canalized rivers, filtrations of water under the foundations are inevitable. As these can not be avoided, it is one of the most difficult problems, both from a constructive point of view as well as for maintenance, to make them as little damaging as possible to the stability of the work. The injurious action of these evils is twofold. First, when they are produced through a joint or fissure of the work itself (in that case the particles of the sand which enter with the water enlarge the opening after a while); second, when the filtrations take place under the base of the work, the soil of the foundation is weakened and the work loses its support and bears unequally upon its base. These two phenomena, occurring separately or together, can very easily destroy the stability of a barrage.

The author had occasion to observe the effects of these causes at the time of taking down a mill barrage on the Spree at Furstenwalde in 1890. This barrage had been built in 1835, and was founded on piles driven between two courses of sheet piling, and on these piles rested the massif of the masonry 0.70 meter (2.30 feet) in height. This foundation carried the barrage, which was formed of fixed posts and a sluice

gate; the height of the water was not ordinarily more than 0.94 meter (3.08 feet). When the barrage was removed it was easy to see that the masonry in general had not suffered any change, while underneath there were cross excavations nearly half a meter deep. The joints in the sheet piling had greatly enlarged, and the platform of the foundation, which was originally formed of squared timber, had deteriorated by the action of the water to such a degree that these squared timbers had lost a large part of their thickness and presented generally the appearance of rough and irregular timber. The mortises of the trusses of the foundation were enlarged, and the tenons did not fill the mortises. It was very clear that after a few decades the masonry in the foundations would have lost its support entirely.

Works destined to prevent the injurious effects of the permeability of the soil.—The work for preventing these injurous effects should not only be applied to the most careful execution of the constructive works, but also to the conservation of the river bed, both above and below the barrage, up to a height corresponding to the upper surface of the foundation. The better anyone can assure the stability of the river bed the greater is the resistance which the water meets in passing from above to below, and the feebler is the current and the less erosive is its action. If, on the contrary, there exists on the two sides of the work excavations in the bed of the river, then the pressure enters into the water, which filters through and wears away the foundations of the work. The author illustrates the method of proper construction and maintenance by two examples, which are shown on Plate (No. 9).

Measures of precaution to take in the construction of barrages.—It is necessary, in the first place, that the sheet piling which surrounds the trenches of the foundation should be executed in as careful a manner as possible, and it is also necessary before driving these sheet piles to carefully sound with an iron rod the entire base and to remove all stumps or other débris that may be found in the bed of the river. He advises that these sheet piles should extend to about 2 meters (6.56 feet) below the lower surface of the béton foundation and to have a thickness of about 20 centimeters (7.87 inches) and to have square tongues and grooves. He gives advice in regard to careful placing of the béton and its proper setting in layers, and that the dimensions in such cases as that of the Oder should be about 1.50 meters (4.92 feet) in thickness. He also advises that great care be taken in laying the masonry upon the béton, in order to avoid filtration through the joints which separate the stones of the foundation; otherwise, if this is not carefully attended to, openings, which the water will certainly find, will enlarge the joints little by little until it will be necessary to renew the work.

In the case of a river the bed of which is composed of impermeable clay the danger of infiltration is less, but it is still necessary to employ

sheet piling and great care in the execution of the work. The ideal location is, of course, solid rock, but even then the upper courses, if the rock is limestone, should be removed, as they are often friable, and, when exposed to the action of the water, often disintegrate.

Measures to take to protect the bed of the river.—The plan suggested by the author is seen in the plate above referred to, the one important feature of it being a downstream foundation extending about 20 meters (65.6 feet) below the lower courses of sheet piling. This rear foundation is composed of fascines about three-fourths of a meter thick which are loaded with rock one-third of a meter in thickness.

The maintenance works.—The suggestions in regard to these are confined mostly to taking care of excavations due to scour that may form above and at the corners of the foundations. He stated that the works themselves—that is, the masonry—do not often require much maintenance work when the original work is carefully done. When, on account of settlement of foundations, fissures or even cracks have opened in the foundation, it is possible, without drawing away the water, to fill these fissures by means of cement grout, which is forced into the apertures by pouring it into an iron tube, the top of which reaches above the water.

Third question.—Utilization of the fall of water at weirs as a motive power. Means of utilizing such power at ordinary times for the traction of boats and for work to be performed in the interest of navigation. Utilizing the velocity of the streams during high water.

PAPER BY MR. J. HIRSCH, OF FRANCE.

While the problem limits this question to canalized rivers the writer considers it permissible to extend it to canals, as there are more interesting features of the question in the latter than in the former. He proposes to confine his remarks to French navigation and let his foreign colleagues take up questions belonging to other countries. In reference to France there are but few instances where the fall of water has been utilized; so far it has been done in three ways only.

1. In the utilization of the velocity of currents.
2. In the utilization of the fall for maneuvering the works of canals or rivers.
3. In utilizing this fall for traction of boats.

1. UTILIZATION OF THE VELOCITY OF CURRENTS.

The author is able to bring forward but one application of this kind, which was made many years ago upon the Upper Rhone, at the rapids called the Falls of the Rhone. (For more detailed description see Annales des Ponts et Chaussées, 1887, second section, p. 653.) A flat-

boat was used carrying two large pendant wheels which were revolved by the current. These wheels could be connected at will with two drums. One of these drums received a cable made fast to a fixed point. On the other drum the towing cable unwound from the boat that was to be towed.

2. UTILIZATION OF THE FALL FOR MANEUVERING THE LOCKS.

When the barrages are up and a fall of water exists, this fall gives a motive power which generally is important. It is often utilized for running mills and for other industrial purposes. It is very easy to use a part of it for maneuvering the locks. The author gives several instances where the fall of the water has been used, as follows:

The locks of Bougival. These are on the Seine, and were one of the first instances where the fall of water was used at a lock. This barrage was entirely rebuilt between 1879 and 1883. There are three locks, an old one and two new ones, side by side. It is at the two latter that the hydraulic plant has been installed. The normal fall is about 3.20 meters (10.5 feet), the volume of the Seine at this point being about 50 cubic meters (1,766 cubic feet) per second. The horsepower corresponding to the fall is about 2,000—750 of which is employed for lifting the waters of the Seine for use at Versailles. The hydraulic appliances for handling the locks are as follows:

Eight hydraulic presses which handle the gates of the locks; eight for handling the sluice valves for emptying and filling the locks; ten capstans for hauling the boats. Two turbines of 14 horsepower each furnish the power for this hydraulic work.

The new locks of the Canal St. Denis.—These were built in 1880–1885 and are operated by hydraulic power derived from the fall of water which operates the turbines, which with the transmissions and service galleries are placed in the side wall common to the two locks, which is about 6 meters (19.68 feet) in width. The power is hydraulic at some locks and mechanical at others. In both cases the arrangement provides for delivering the water to the turbines at the commencement of the maneuver and withholding it when the maneuver is completed. A turning bridge of clear opening of 15 meters (49.2 feet) is also operated by hydraulic pressure.

The derivation of the Scarpe near Douai.—These works were completed in 1893–1895. (See Annales des Ponts et Chaussées, second section, 1896, p. 568, for detailed description of the work.) There are 2 pairs of locks side by side 38.50 meters (126.18 feet) long and 6 meters (19.68 feet) wide. The 2 locks of each pair are separated by a wall 8 meters (26.24 feet) wide, which contains the galleries for the service of the work. The gates are of the single-leaf type. The maneuvers are made as at the canal of St. Denis by a turbine which operates upon the gates through power mechanically transmitted and also operates 4 capstans.

Lifts for canals.—The author simply refers to the well-known lift at Fontinettes on the canal of Neuffosse and gives the opinion that what he calls this costly experience will not be repeated, he thinks, for some time to come—evidently not agreeing with the general opinion that these lifts were very successful.

The inclined plane of Beauval.—This is described in the Bulletin de la Société d'encouragement pour l'industrie nationale, 1893 (p. 633). The object of this incline is to transport boats between the Ourcq Canal and the Marne, avoiding a tortuous course of 100 kilometers (62.19 miles) and the passage of numerous locks. The boats transported have the following dimensions: Length, 28 meters (91.84 feet); depth, 1.20 meters (3.93 feet); width, 3.10 meters (10.17 feet); weight, empty, 16 tons; weight, loaded, 70 tons. The distance between the Marne and the canal is only about 550 meters (1,804 feet); the elevation to be made is 12.15 meters (39.85 feet). There is a basin excavated at each end. The two basins are connected by an iron track on which moves a car; this car is drawn down into the basin and receives the boat which is fastened on the platform of the car. The hauling is done by a telodynamic cable operated by turbines utilizing the fall of the barrage. The pulleys on which this cable acts are on the car and communicate movement to a pinion which takes hold of a rack, of the Riggenbach system. This rack is fixed along the central part of the railroad. The car is built of wood with an iron frame, with a wooden platform on which the boat rests. It rests on two double-axle trucks. An overhanging iron frame fixed on the car receives the pulleys and the footway for the employees.

There are two grades, one ascending and one descending, one being 4 per cent and the other 6 per cent. There are four lines of rails. It is arranged so that the parts will work easily whether on the grade or on the level of the basin. A system of brakes, with a centrifugal regulator, serves to regulate the speed of the descent. The car weighs, empty, 35 tons.

The cable is 12½ millimeters (one-half inch) in diameter, moving at a speed of 15 meters (49.2 feet) per second, which gives a corresponding speed of car of 0.25 meter (0.83 foot). The turbine which operates the railroad is actuated by a fall of water of 1.60 meters (5¼ feet), only a small part of the volume of the Marne. It will develop more than 25 horsepower. The whole movement from basin to basin lasts about 40 minutes. The double trip can be made in an hour and a quarter. This entire work did not cost more than 100,000 francs ($20,000). It works very regularly.

Pumping water for canal levels.—This is done on the canals of the center of France and of Bourgogne by pumps actuated by an electric current taken from the fall of water at the barrage or at reservoir dikes. These interesting installations should be the object of special communication to the Brussels congress.

Movable dams.—The author simply refers to numerous applications on even very old works of motive power derived from the fall of water in handling the maneuvering apparatus for sluice valves, gates, and other features of the barrage.

3. UTILIZATION OF THE FALL OF WATER FOR THE TRACTION OF BOATS.

This question was treated in a very careful manner at the Congress of Navigation held at The Hague in 1894. There were numerous systems of such traction examined by that congress. In the present state of this method only two kinds of transmission have been realized—by mechanical appliances and by electric currents.

Chain haulage.—The mechanical traction has been attempted up to the present only under the form of cables moved continuously and to which the boats are attached by their own towlines. This system has been particularly studied by former congresses. It has been also the object of very extensive experiments upon the canal Saint Maurice. It is now about to receive a practical and important application on the tunnel of Mont de Billy, on the canal of l'Aisne on the Marne. (See Annales des Ponts et Chaussées, 1897, second section, p. 267.)

In the preliminary experiments which we are about to mention the cable was moved by a steam engine, but nothing prevents the application of a hydraulic motor actuated by the fall of a barrage, and the system appears entirely appropriate to this method, but up to the present time we do not know of such an example in France.

Electric haulage.—This problem has been solved, particularly at the tunnel of Pouilly, on the level of the canal of Bourgogne. The dynamos which send the electric current to the towing boats are moved by turbines actuated by the fall of water at the canal. The success of this work was so remarkable that one of the inventors was given the mechanical prize of the foundation Monthyon of the Academy of Sciences, and was the subject of a complete description at the congress of The Hague.

The Bovet system.—The same congress occupied itself with the question of towage by magnetic adherence, employed with success by M. de Bovet. This attractive system has recently been experimented upon on a large scale in the levels of the canal St. Denis. (See Bulletin de la Société des Ingenieurs Civils, January, 1895.)

The boat to be towed grips a sunken chain by means of a pulley with a magnetic adherence, put into motion by a dynamo. A double aerial conductor placed on poles planted on the bank furnishes the direct and the return currents by means of trolleys of a special form, which allow the boat to move out into the stream a considerable distance from the bank. The electric current serves at the same time to actuate the dynamo mounted on the boat and magnetize the adherence pulleys. The whole weight of the dynamo and the transmission apparatus and

the pulleys is very little. The system works regularly, and experience with it shows it very recommendable. The electric energy is developed by a steam engine; it could as well be developed by a hydraulic motor.

Denefle system.—Experiments of great interest were made in 1895 and 1896 by Mr. Denefle on the levels of the Bourgogne Canal by electric traction. (See Moniteur des Industries Electriques, 1897, p. 322.) The motive power was taken from the fall of water at one of the locks. This fall of 2.60 meters (8.53 feet) actuated a turbine, which gave the movement to a dynamo. The current was carried on a double aerial wire, and this current received by trolleys transmitted by flexible conductors to the traction apparatus. Two systems were tried. In the first system the propeller is a screw carried by a little boat, which takes the place of the ordinary rudder; in this boat was placed the dynamo, which actuates the screw. The other system is a veritable electric horse, moving on the towpath. It is of tricycle form, moving on three wheels, with wide tires. The forward wheel is a directrix to the rear wheels or motors, and moves by adhesion upon the ground. One very ingenious arrangement assures the convenience and the security of the motion. The towpaths are not damaged at all by the wide wheels of the machine. The apparatus has shown itself tractable, sure, and easy to handle. It hauls without difficulty a loaded canal boat at a speed of about 3 kilometers (1.86 miles) an hour. It can haul four boats.

Mr. Denefle has organized a company for operating on the navigable lines of the north of France (Aire, Deule, Scarpe, and Sensée).

Experiments on the Saone.—The engineers have made careful researches with the object of utilizing for towage the falls of the barrage established on this river. These experiments are now being made, and the conclusions are not yet formed. The résumé and conclusions of the paper are mostly repetitions of the previous statements, and it is not necessary to reproduce them.

PAPER BY MR. ROEDER, OF POTSDAM, GERMANY.

The utilization of hydraulic force is of ancient origin. Even rivers of considerable importance were provided with numerous works, principally for the purpose of drawing off part of the hydraulic force. There can be cited among rivers in the north of Germany where such use has been made of hydraulic forces, the Lahn, the Ruhr, the Lippe, the Saale, the Havel, the Spree, and the Oder. These barrages served frequently to facilitate the navigation, and in this case the locks were established at the site of the barrages; but upon the development of steam machines hydraulic forces for these purposes lost their value, as they did not guarantee a uniform force, and their utilization could not always be effected at a convenient location. The steam machine,

on the contrary, could be installed anywhere and its output easily made to conform to all requirements. In later days, however, hydraulic force has attracted more attention, since electricity has been developed, which permits the utilization of hydraulic force in locations more or less removed from its source. Installations on a large scale have been made on the Niagara, the Rhine, near Schaffhausen; the Rhone, near Geneva; the canal of Jonage, near Lyon, and on rivers of large volume in the Alps. The barrages which have been established during recent decades in connection with the canalization of rivers generally waste great quantities of superabundant water. This fact naturally encourages the project of utilizing this waste force either for general purposes or with a view of drawing some of the benefit from the force thus lost for the purposes of the works of canalization themselves.

In fact, for this purpose and on a scale more or less large the motive force has been used on the canalization carried out in Germany and in other countries as well. Recent canalizations, however, have works entirely different from those formerly employed. The old barrages were fixed and their crown established so that the fall of water was not subject to fluctuations, but the plan at the present time requires these dams to be let down, and thus the hydraulic force is destroyed in times of flood and under other conditions; consequently the utilization of these hydraulic forces is not as easily made.

Conditions which relate to the utilization of hydraulic force.—As the canalization of rivers extends the interest increases in this subject. In isolated cases propositions have been made with this object in view by private parties. The Prussian minister of public works had already in 1892–93 established the basis by which private parties could make use of hydraulic force on State works. Briefly the conditions were that such forces could be leased but not sold by the State, and the use of this force for the purposes of the State always had the preference. In general the landed proprietor could make use of the extra hydraulic force, but the State reserved the privilege of withdrawing this right at any time.

Hydraulic force available in Prussia.—The writer then gives a table showing the amount of force and natural conditions of it upon seven rivers of this part of Germany. A summary of this table shows that there are 40 levels where there is a sufficient fall for hydraulic purposes, a total of about 11 meters (36 feet), a total volume of 3¼ cubic meters (114.76 cubic feet) per second, and a total horsepower of 11.576. In addition to these rivers, which are the Lower Brahe, Upper Oder, Fulda, Ems, Main, Saar, the final canalization of the Weser—the Munden—at Bremen, will comprise about 50 barrages.

Has the time come to reconsider the use of hydraulic forces?—Experience acquired up to the present time is not very favorable toward an affirmative answer. Wherever the old fixed barrages exist the fall

of water may still be utilized. On the other hand, as has already been stated, the barrage with needles is not as easily utilized. For the purpose of examining special rivers in Germany to ascertain the extent of the proper utilization of the hydraulic forces a proposition has been made to the State by Mr. Siemens to make full examinations.

Two important examinations have been published, one by Messrs. Werneburg (Central Blatt der Bauverwaltung, 1897, Nos. 42a and 45), the other by Prusmann (Zeitschrift des Binnenschiffahrt, Jahrgang V, heft 2 and 3), the first treating of the utilization of a fall in the canalization of the Saar and the other by a level to be created upon the canalization in the Weser. Details of these examinations follow.

Mr. Charles Von der Heydt has invented a floating barrage allowing the passage of the running water and developing a hydraulic energy gathered by accumulators installed on the bank. Up to the present time there are no practical results from this invention.

It has been proposed to transform the barrages of canalized rivers into fixed barrages, but the writer disapproves of this for the reason that it would result in very prejudicial effects by interfering with the movement of floods and of ice, and other serious objections are mentioned which are too patent to require discussion.

The experience thus far acquired proves that the utilization of hydraulic forces after the completion of a canal can not be successfully accomplished on account of the excessive cost of the installation to adapt them to a situation which was not contemplated when the works were built. The author recommends that the use of water for such purposes should be had in view when any new works or canals are planned and carried out by the Government.

From the various considerations stated in the paper the author gives the following conclusions: (1) The waters of rivers of the public domain ought to be destined in the first place to navigation and to the general uses of the public. (2) If beyond these requirements, which ought to be studied in view of the eventual increase of these needs, there is an excess of water it could be disposed of and made to serve as a motive force on the condition that such utilization would be justified from a technical and economical point of view. (3) In case of such utilization of motive forces it would be best to establish the installations at the time the canalization of the river is made. (4) The hydraulic force belonging to the State, if it can not be utilized at the time, should not be alienated, but simply leased under stipulations of the most severe kind regarding the public interest, and the hydraulic force used should be devoted to the exploitation of common interests. (5) The utilization of hydraulic force may be considered as advantageous when the net revenue suffices to cover interest and payment of principal of securities outside of running expenses.

PAPER BY E. D. MARTEN, OF ENGLAND.

The author gives two important advantages which ordinary water powers have which are not applicable to the force at barrages, namely, a comparative immunity from "tail-water" and a head that may be drawn down at will. In a mill stream the water is usually carried along the hillside and the mill placed at a height above the tail-water, even in times of considerable flood in the river, but in a navigation the barrages are always constructed in the main stream with a view to as little obstruction to floods as possible, therefore there is a much more rapid rise in the river in the channel below the barrage than on the crest of the barrage itself. The author presents a very effective diagram to illustrate these objections, giving the conditions as they appear in low water, in freshets, and in floods at the Diglis barrage on the River Severn. (See No. 10, which explains the situation which the author gives in considerable detail in the text.)

It is his opinion that when knowledge of the art of storing electricity shall be sufficiently developed the irregularity in the fall and flow at barrages will be much less in consequence than it is at the present time. He considers that neither electric lighting nor electric haulage could be economically worked from such a source at present. He gives an illustration of the difficulty of manipulating the level above the barrage in the same way that a miller would manipulate his mill, and which is necessary in order to obtain the necessary regular force for electric use.

In his conclusions, which the above remarks cover quite well, the author gives a suggestion of importance, that when our knowledge shall have been fully attained in reference to the use of hydraulic force for electric purposes it will only be possible to utilize the power by building a second weir level with and downstream from the principal barrage and taking the power from between the two.

Fourth question.—Resistance to the movement of boats. Influence of the shape of boats and the condition of their surface upon resistance to traction.

PAPER BY CAPT. C. V. SUPPAN, OF VIENNA.

Stimulated by the researches made by M. de Mas, the results of which are given in his paper before the Fifth International Congress of Navigation, at Paris, the Steam Navigation Company of the Danube made, in 1895, a series of experiments upon the resistance of boats to traction.

These experiments were made upon various types of towed boats of 820, 700, 650, 580, 450, 380, 320, and 200 tons regularly employed in the Danube traffic. They furnished very interesting data, which can not all be published at present for reasons, but the author undertakes to communicate to the congress at Brussels that part of the results relative to the discussions.

He gives first the information in respect to the manner of making the experiments and describes the instruments of precision which were adopted, which were made by the firm of Richard Freres at Paris. These were made for the purpose of meeting the peculiar conditions which existed on the Danube, and were applied to a side-wheel steamer of 600 indicated horsepower, 62 meters (203.36 feet) long, 7.30 meters (23.94 feet) beam, 2.70 meters (8.85 feet) depth, and 1.10 meters (3.6 feet) draft. The steam engine of this boat was of triple-cylinder motion, with three cranks coupled at 120°. There is obtained in this way, not only when the boat is moving at low speed but also with high speed, a uniform movement and a steady and continuous traction. The resistance of this boat itself was also determined by towing it by a still more powerful steamer. (See Plate II, fig. 1 (No. 12).)

The author enumerates the instruments used, which were hydraulic dynanometers for pulls of 3 to 10 tons, 3 manometers of the same resistance, a current-measuring machine, and a hydraulic registering apparatus.

The experiments were made on a straight part of the river, 5 kilometers in extent, just above Budapest, and they were made during the months of June and July, when there was very little change of level in the river, and during the experiments the mean width was about 200 meters (656 feet), and the mean depth 3 meters (9.84 feet). The experiments made under the direction of Mr. J. Spacil, president of the technical department of the company, were upon 26 iron towed boats and upon two types of boats in wood, with a total of 281 experiments, which would make about 10 to each boat.

Each boat was at first towed with the maximum draft, that is with a full load. The load was then reduced to one-half and then to one-third, and finally the boat was towed empty, and each boat under the above conditions was towed at velocities varying between 7 and 18 kilometers (4 to 11 miles) per hour. The velocities were calculated on the basis of movement in tide water.

In reference to the two questions before the first section of the congress, namely, the form of boats and the state of their surface, the following results appear:

A. EFFECTS OF THE FORM OF BOATS.

This effect is very small in comparison with the resistance due to friction of the water against the immersed section of the boat.

Representing the total resistance at 100 per cent, the resistance of traction resulting from the form of the boat is only from 5 to 20 per cent for the merchandise boats of the company.

For other towed boats used on the Danube the resistance due to form varied from 7 to 30 per cent of the total resistance, according to whether the form was more or less "fine."

It should be remarked, referring to this point, that the above results refer to resistance when the towed boat is moving in a right line against the current, that is with the drift of the current parallel to the longitudinal axis of the towed boat. If the direction became oblique to the current the resistance increased very much. In this case the resistance to be overcome resolved itself into three parts: (1), the resistance of friction; (2), the resistance of the original form, and, (3), that resulting from the pressure of water upon the projection of the longitudinal face of the boat and upon the rudder.

Some forms of boats did not permit of control by the rudder, especially those where the stern was too full, and in these cases the resistance due to form was considerably increased.

The boats of the company are generally easily directed when the velocity does not exceed 15 kilometers (9.32 miles) an hour; for this velocity the resistance due to form is 15 per cent.

There are several types of boats employed on the Danube where, when the velocity passes 15 kilometers per hour, the resistance increases very rapidly.

It should also be remarked upon this subject that in towing boats by means of side-wheel steamers the waves produced by the wheels have little effect upon the boat towed when the speed is increased.

After giving some comparisons in respect to different boats experimented upon, the author makes the remark that the difference in resistance by using various types of boats is not great for the same immersed surface.

A table comparing a model barge with a barge of the spoon form in front shows that the model barge has the advantage. The latter of 320 tons at 9 kilometers per hour, loaded with a wetted surface of 400 square meters (4,306 square feet) showed a resistance to traction of 490 kilograms (1,078 pounds), while the model boat of the same load, same speed, same wetted surface, showed 420 kilograms (924 pounds). (See Plate I (No. 11) for forms of these boats.)

At 18 kilometers per hour the difference is still greater, the "spoon"-form boat showing 2,420 kilograms (5,335 pounds) resistance, and the model boat 1,940 kilograms (4,277 pounds).

The author calls attention to the fact that below a speed of 7 kilometers (4.3 miles) the two forms show very little difference, but above that speed the spoon form shows a considerable greater resistance, due probably to the fact that it is not so easily directed.

He therefore concedes that for low speeds, such as would usually be found in canals, the spoon form may be convenient, but in the navigation of a river at high speed this form is not suitable.

B. EFFECT OF THE CONDITIONS OF THE SURFACE OF BOATS.

This effect is much greater than that from the form of boats.

To show the effect of surface comparative experiments were made with 2 boats of 650 tons of identical form, but of different ages. (See Plate I, fig. 1 (No. 11).) The excess of resistance of the older boat, which was five years older than the other, was as follows:

	Per cent.
With a draft of water 0.40 meters (1.31 feet)	14
With a draft of water 0.95 meters (3.12 feet)	12.2
With a draft of water 1.45 meters (4.76 feet)	6.1

Another experiment was made with a boat of 220 tons capacity, which had a smooth surface but was made rough by means of pitch put on in ridges. The resistance of this boat was 27 per cent greater than that of one with a smooth surface. (See Plate I, fig. 4 (No. 11).)

Comparative experiments were also made upon wooden and iron boats of the same capacity. The difference was so pronounced that the author remarks that the use of wooden boats is entirely irrational. He even calls such use an economical absurdity. He gives one example of this comparison, which showed that the resistance of the wooden boat with a draft of 0.45 meter (1.47 feet) was 33 per cent greater than that of an iron boat, although the mid section was less than that of an iron boat by 10 per cent. With a loaded boat having a draft of water of 1.60 meters (5.25 feet) the resistance of the wooden boat was 89 per cent greater than that of the iron boat, of which the draft of water was 1.80 meters (5.9 feet).

He makes a still further comparison between wooden and iron boats, where the draft of the former was 1.80 meters (5.9 feet) and the latter 1.60 meters (5.25 feet), both with the same load, about 450 tons. The resistance of the first boat was 94 per cent greater than that of the iron boat.

As a result of the experiments, the author states that the cost of traction per kilometric ton with a wooden boat is about double that with an iron boat, and for this reason the wooden boats should be removed from the navigation as soon as possible.

Outside of these experiments it is generally known upon the Danube, by a number of years' experience in actual traffic, that a towboat can tow 7 iron boats where it is able to tow but 4 wooden boats with the same load. Old wooden boats, where the bottom has become rough and uneven, present a particularly great resistance of surface to traction.

Referring to the results of experiments made by Mr. de Mas in 1890–1893, he states that upon the Danube the resistance of form is *not* important, but the resistance of surface *is* important.

In reference *to effect of length of boats*, the results of the Danube experiments do not agree with those obtained by Mr. de Mas, who had come to the conclusion, from his own experiments, that within certain limits the length did not exercise any influence upon the total resistance, but upon the Danube, on the contrary, comparing resistance of boats of identical construction of the same immersed depth and having the same midship section, the longer offered a much greater resistance than the shorter boat in limits of length, equal to 10 meters (32.8 feet).

A towed boat of Class III, of 53.90 meters (176.84 feet) length (see Plate III, figs. 5 and 6 (No. 13)), showed, when empty, with a speed of 18 kilometers (11.18 miles) in tide water, a resistance of 1,240 kilograms (2,728 pounds), while a boat of the same class and same construction about 64 meters (209.92 feet) long showed for the same immersed depth a resistance of 1,340 kilograms (2,948 pounds).

The author gives a very complete table of all of the conditions and results of all these various experiments, to which reference should be had for more detailed study.

Upon the Danube the proper speed for going upstream is about 5 kilometers per hour near the banks, which corresponds to a speed in dead water of 9 kilometers; that is, upon the Lower Danube. Upon the Upper Danube the speed in dead water would be about 13 kilometers.

Comparing four of the types given in the table, namely, of 650, 350, 320, and 220 tons of capacity, respectively, the 650-ton boat (see also Plate I, fig. 1 (No. 11)) shows the least resistance at 9 kilometers (5.59 miles) per hour in dead water, or, respectively, as follows: Per kilometric ton of load 1, 1.2, 1.5, 1.7. At 13 kilometers they are as follows: 2.3, 2.6, 3.3, 3.7.

The 650-ton boat is at present the standard type of the Danube traffic. At the end of 1897 the navigation company had a fleet of 108 steamers, with a total horsepower of 63,480, and a fleet of 864 barges with a total capacity of 363,805 tons. Since 1889 it has built 206 boats of the above normal type.

The author gives the quite important method of operation in reference to the employees of this company. Each one receives a fixed pay and a variable pay. The latter is dependent upon the kilometric tonnage, gross or net, per voyage, based on the coefficient of resistance of the steamer in question, the coefficient of resistance of each of the towed boats, and the coefficient of the load. This method extends to every one on board, from the captain to the firemen.

The conditions under which the voyages are made are taken into account; such as obscurity of the nights, violent tempests, and fogs. In this way the relation between the work effected and the remuneration for it is established justly on scientific bases. The matter is mentioned for the purpose of showing that the experiments were of great value practically.

The data which serves as a basis for this system of remuneration are also employed in the nautical office for the purpose of determining the kilometric tonnage and the price of the same applied to the freight.

The author states that, independent of transportation of travelers and other services, there is now upon the Danube about 1,000,000,000 kilometric tons, net (referring to the load), or 2,000,000,000 gross kilometric (for the load and the resistance of the towed boats) tons, covering 4,173 kilometers (2,592 miles) of navigable channels.

PAPER BY B. DE MAS, FRANCE.

If we assume a boat floating on the surface of fresh water of unlimited extent, the total resistance to traction depends upon its dimensions, its form, nature, and state of the surface, and on its speed relative to the water; but all these elements pertain to the boat itself. If the same boat is put on another and similar stretch of water the resistance will be the same. If, on the other hand, this boat is found on a navigable waterway of limited dimensions, like a canal, its resistance to traction is modified. To appreciate the results of this latter we are led to compare them with those obtained in an unlimited extent of water, and to consider the resistance of the boat as equal to its own resistance multiplied by a coefficient which represents the special influence of the channel, which constitutes the coefficient of resistance of this waterway.

Designating this coefficient by C, and by R the resistance to traction of a boat upon it, and by r the resistance of the boat itself, we have the equation $R=Cr$.

The dimensions of canalized rivers are extremely variable. If the mean width and depth are both considerable the river can be compared to an unlimited water area, its coefficient of resistance not differing sensibly from unity. If, on the other hand, one of these dimensions is sufficiently reduced, the similarity cannot be maintained, the coefficient of resistance takes a value much superior to unity.

The author gives a complete résumé of researches which he had made, and which were published from 1891 to 1897 under the title of "Recherches Experimentales sur le Materiel de la Batellerie."

His researches were made on wooden boats of dimensions prescribed by the laws of France for canals—that is to say, measuring at most 38.50 meters (126.28 feet) long, 5 meters (16.4 feet) wide, 1.80 meters (5.9 feet) deep. The principal results which he has obtained refer to the following points: (1) The nature and state of the surface of the hull have great influence on the boat's resistance; (2) this resistance is independent of the length of the boat, at least within the limits where the length has varied under his experiments; (3) this resistance can be modified by changes apparently of little importance made upon the

form of the bow and of the stern, and the author has been led to recommend for the two extremities boats of spoon form.

The author then enters upon a discussion to show the incorrectness of the formulæ generally admitted up to the present time for representing the resistance of the boat itself.

$$r = K \Omega V_2$$

in which Ω is the surface of the midship section immersed; V, the speed relative to the water, and K, a coefficient constant for boats of the same form.

He proposes from the experiments which he has made to more conveniently represent the resistance by the expression:

$$r = (a + bt)\ V\ 2.25.$$

in which (a+b) would be constants characteristic of each type of boat.

Coefficient of resistance of the waterway.—Are the forms recommended for navigation of unlimited waterways suitable for navigable waterways of limited dimensions? From the author's experiments the different types of boats preserve in restricted waterways the order of resistance in which they had been classed in unlimited waterways.

The author discusses the well-known formulæ of Du Buat and Sweet and states that he has found that the section had an influence on the resistance. On the two canals the wetted cross section is exactly the same, but on one canal the depth is only 1.70 meters (5.57 feet), while on the other it is 2.06 meters (6.75 feet). The coefficient on the latter shows a marked reduction up to 13 per cent. He holds that it is indispensable that the changes in section should not be sudden and that there should be continuous and sufficiently extended curved surfaces in the banks.

The resistance to traction, other things being equal, will be less in a waterway where the banks are protected by a smooth revetment than in one where the same banks are covered with a vegetation more or less uneven. He states, also, that it is possible to calculate approximately the numerical value of the coefficient of resistance of waterways found in certain conditions.

He discusses the results obtained by Professor Engels, of Dresden, in developing the navigation of rivers and canals in Germany, where models exactly similar to natural conditions were used, and where the laws, according to Froude, were proven to be correct.

The author believes that by such models it would be possible to resolve the problem of determining the rational cross section of canals which the congress at The Hague brought forward, and in doing this it would be necessary to develop everything relating to the form of the cross section and to consider successively the rectangular and the

trapezoidal form, each of which could and ought to be employed alternately on the same canal according to the nature of the land and the exigencies of the localities traversed.

It is still necessary that investigations should be made upon the nature and conditions of bank surfaces, or, more exactly, upon the character of work to be undertaken for the protection of these banks, specially near the surface of the water. The author does not hesitate to state that he considers it improper in a navigable waterway of restricted dimensions to use any system which has striking irregularities in the section of the banks and the development of vegetation, and in every case the surface which is required to be permanent should also be smooth.

In conclusion, he proposes to submit to the congress at Brussels the following resolution: "The congress considers that it is time to reproduce by means of models some of the experiments made on a large scale by Mr. de Mas, not only upon the Seine (researches to obtain the resistance of the boat itself), but in canals (for the determination of the coefficient of resistance), in such a manner as not to leave any doubt on the point that Froude's law could be applied safely in one case as well as in the other." The problem of the rational determination of the section of canals ought to be easily solved if once this point be settled.

PAPER BY OSWALD FLAMM, OF BERLIN.

The author gives a historical résumé of the efforts to determine exactly the resistance of a body of some form moving in water. His résumé begins with the sixteenth century by Newton's investigations and the results of work by Bernouilli and Euler about fifty years after; in 1769 by Admiral Thevenard, and in 1786 by Du Buat, by Beaufoy in 1793; 1850–1860 by Bourgeois and Scott Russell, and later by Rankine.

The very rapid progress in recent years in the construction of vessels and the extension of commercial relations between countries far removed from each other made it necessary for the vessels to travel long distances as quickly as possible and this brought about new conditions and requirements.

The result of these investigations and the establishing of formulæ for building vessels has led to uniformity to such an extent that the forms of modern boats do not show as wide a divergence as formerly, especially during the epoch of transition from construction of wood to iron and during the first years of the employment of iron.

The most remarkable results in the development of the form of vessels has been obtained by Froude, whose observations and laws up

to this day are the basis, not only for establishing new formulæ of resistance, but also for the organization of experiments.

In our day it is generally admitted that the resistance to the movement of a boat is subdivided really into two principal parts, namely, the resistance of friction and the resistance of form.

In order to be able to determine exactly the resistance to movement it is necessary to be acquainted with the coefficient of friction corresponding to each surface, and here the experiments of Froude have been of great use.

It is much more difficult to examine the second part of resistance, namely, that due to form, and to determine its value. It seems impossible to solve this question in a theoretical manner, and up to the present time it has been necessary to proceed entirely in an experimental manner. Experiments on a full sized scale are naturally very difficult and very expensive and only governments can undertake to meet the expense. For this reason the experiments of Froude have been of very great service, because, by means of a very ingenious machine, he caused models of paraffin to imitate very exactly the form of great ships, and submitted these models to experiments in a basin constructed expressly for this purpose.

A factor of resistance to movement is the influence of the propeller. There is no doubt that the labor of the screw behind the vessel increases the total resistance. This Froude has demonstrated.

So far the author has assumed that the vessel is moving in an unre stricted waterway, but the situation becomes entirely different when the resistances are measured in a restricted waterway.

It is generally well known that the relations of the immersed section, or midship section, to the section of the canal is of great importance. The fine experiments which have been made on canals in France by Mr. de Mas have shown that the most favorable form of vessels on canals is the spoon form.

The section of the canal not only exercises an influence on the resistance of the boat, but also equally the relation between the immersed section at the midship section of the boat and that of the canal.

The author goes at some length into the results obtained by Professor Engels, already spoken of in the paper of Mr. de Mas, and produces a plan (No. 14) where the resistance in different-shaped sections of canals are given.

He calls attention to the fact from this diagram that if the boat employed has vertical lateral sides, and the section of the canal also vertical sides, like profile No. 1 (No. 14), the resistance is least. In all the other profiles the widths of the lateral masses of water go on diminishing rapidly from top to bottom, so that consequently there is a great difference between the respective velocities of these masses

making friction the one against the other and increasing in this way the resistance compared with that on profile No. 1.

The coefficients of these considerations can easily be verified by giving to the section of the boat a form like that of the extreme sections of the canal, for example, profile No. 5.

The author recommends, as does Mr. de Mas, that on account of the great expense of making experiments on a large scale the same result can be obtained much more economically by the use of models of reduced scale, in order to solve all of the questions which up to date remain unsolved.

CHAPTER III.

SECOND SECTION—INLAND CANALS.

First question.—Modes of mechanical traction along canals; improvements realized or proposed since the Congress at The Hague in 1894.

PAPER BY E. CHENU, OF BRUSSELS.

This paper gives the history of various methods of traction on the canal from Charleroi to Brussels and the results of some quite extended experiments that have recently been made in electric traction.

The view expressed at The Hague that the question of the proper method of traction is not susceptible of a general solution, but must be adapted to the special requirements of each case, is confirmed by the author.

Briefly, the canal which was opened to navigation in 1832 connects the basins of the River Sambre with that of the Meuse, the latter connecting with the Scheldt. The original section was very small, capable of transporting boats of only 70 tons. At present quite a large portion of it has been enlarged to carry boats of 280 tons. The route of the canal is shown on the plate (No. 15).

The main line is 73.289 kilometers (45 miles) long. The total length, including branches, is 90.388 kilometers (56 miles).

The canal connects two watersheds, the first, that of the Sambre, having a total fall of 21.377 meters (70 feet), made by means of 11 locks, and the other, that of the Seine, of 107.807 meters (353.6 feet), with 44 locks. The dividing level, of a length of 11.211 kilometers (7 miles), includes a wide tunnel, measuring 1,050 meters (3,445 feet) in length.

Boats of 5 meters (16.4 feet) beam and 1.80 meters (5.9 feet) draft can traverse the canal.

The history of the haulage shows that after many experiments and the use of a variety of methods, and by means of a company organized for the purpose, it was found that the ordinary method by horses was the best and the cheapest.

It would be of no special interest to describe the methods of a drowned cable and by a moving cable and locomotives upon the banks, and other methods which failed and were removed.

The author gives two facts in regard to cost which may be of interest. With the 70-ton boats, which are often hauled by collars upon men, the cost per kilometric ton is 0.10057 franc ($1\frac{6}{10}$ mills per ton mile). The cost of 2 horses for each boat of 280 tons on the large section is 0.00345 franc (1 mill).

The importance for general purposes of the experiments upon this canal arises from the fact of its importance, it being the main waterway between Antwerp and Brussels.

Discussing the question of the most advantageous method of traction, the subject is divided into, first, *traction by animals.* This can not be reduced below the present cost. Second, *by locomotives and towboats.* The canal is too full of locks to permit of navigation by convoys. The additional time lost at each lock would not be compensated for by the additional speed. Third, *funicular haulage.* This also offers a great many inconveniences and dangers on account of the crowded condition of the navigation by all sorts of boats. Fourth, *electric haulage.* In 1895 Denefle & Co. were authorized to make experiments in electric traction on the Bourgogne Canal, which has already been described in a previous paper and was simply an electric tricycle with large wheels.

The author refers to an important description and discussion of various modes of traction on interior waterways published in the Annales des Travaux Publics de Belgique, fourth number, 1896, in which the authors, Mailliet and Dufourny, inspector-general and chief engineer, director des ponts et chaussées, describe fully the apparatus used on the Bourgogne Canal, to which reference has been made.

These authors showed that important progress had been made in the system of electric traction, and at the present time, due to competition between various systems of electric traction, the question is brought down simply to one of cost. At the writing of the paper Denefle & Co. had a proposition before the Belgian Government for an installation of their system on the various waterways of Belgium.

On the basis of the speed which can be obtained without inconvenience and without injury to the banks—3.5 kilometers (2.17 miles) per hour—the author discusses the advantage in time and other respects which this method would have on canals of small section and of large section. The discussion, which is in great detail, brings him to his conclusions, which are that upon the Charleroi and Brussels Canal the haulage by horses as it is now made is the only practicable solution of the question.

Electric haulage, by the greater speed of the boats, would have the advantage of reducing from four days to three the length of the voyage from Sambre to Brussels and in the opposite direction from three days to two. But the price of haulage, as he has proved by his calculations, would be considerably greater than it is at present, and it

would not be less than the present price until there should be a very considerable increase in the traffic, which increased speed would not bring about.

PAPER BY MR. GRÖHE, OF GERMANY.

For many years a great number of engineers of every nationality have endeavored to perfect mechanical traction on canals. The papers at preceding congresses, from the first at Brussels to that at The Hague, prove that this difficult question has been worked over in various ways to reach a satisfactory solution. Formerly the only object was to perfect the existing means, but latterly, under the impress of electrical developments, various and diverse solutions have been proposed, and they will in the future be able to compete with existing systems.

The author then takes up and discusses the various methods:

First, by a motor on board; that is, by the screw or by an electric force on the bank working a propeller on the boat.

Second, by a chain or cable towage, either by motive force on the boat itself or by the transmission of an electric force coming from the bank.

Third, by a motor on the bank.

Fourth, by machines moving on rails or electric motors on cables by the Lamb system; and, *lastly, by funicular haulage.*

Without going into his description of these various methods, which other authors have already described, his conclusions and special features will be taken up.

He concludes that movement by a screw upon the boat increases the expense of maintenance and of dredging on the canal, which must be met either by increasing the depth of water or by protecting the bank more solidly. He emphasizes again that the best method of traction without doubt is that which permits an isolated boat to interrupt and renew its course at any point whatever of its voyage without being obliged to be hauled by another boat, which may not always be found convenient and the lockage of which causes loss of time and a sensible loss of water.

All the systems of mechanical traction interfere with navigation more or less, as, for instance, the chain method, which compels the the boat to follow a definite course and causes difficulties in the meeting of other boats, notwithstanding the various ingenious methods of avoiding this inconvenience.

It would be particularly interesting to find out quite closely the price, by the various recent systems of transport, per metric ton of each of them, but the bases of such a calculation are not sure and the conditions on which these systems have been tried are not suffic

general or on sufficiently large scale to formulate a conclusion with safety.

In the plates (Nos. 16 and 17) the author gives the details of various methods of electric traction, the power being taken from wires strung along the bank on poles, and he described particularly the Lamb system.

The special principle involved here is shown in fig. 1–3 in plate (No. 16). On the bank is installed a strong electric cable on a number of poles. Along this cable moves a car or seat, to which is suspended an electromotor. This moving car is connected with the boat by an ordinary cable. The details are fully described in the text, to which reference is made for further information.

Under the head of funicular haulage the author discusses the question of the twisting of the cable, which generally happens, causing a great inconvenience and often danger, and explains how the braided cable is made under the Beck system. This is a square cable, not made in one piece, but by means of from 4 to 8 braided strands made by a machine. Torsional movements are avoided. The main advantageous features of these cables are, first, the square braided cable always presents the same length of meshes at the surface; second, it stretches much less than a circular section; third, the joining of the parts is made so as not to injure the homogeneity of the cable; fourth, it is more flexible, requires less force to make it conform to changes in direction on the curves of the canal, and it is more easily used upon pulleys than a circular cable; fifth, it is more supple; sixth, it does not twist, but moves forward with always the same part of its surface up. The guides are not injured by any twisting, and the cable can be easily unrolled.

He recommends that the advantages of this cable should be brought out by experiments on an extended scale, and states that the company which has the monopoly of its construction has the intention of selecting as a place for experiments the canal from Dortmund to Ems, 30 kilometers long with several levels, and the projects which have been worked out are shown on plate (No. 17). The square cable referred to is stretched artificially under a pull of 4,000 kilograms (8,800 pounds). In straight reaches of the canal and on curves of large radius this cable is separated every 60 meters (196.8 feet) or 70 (229.6 feet) by simple pulleys of 0.35 meter (1.15 feet) in diameter. In order to avoid the sudden oscillation of the cable due to several boats being taken on or off at the same time, or for other causes, the separating pulleys are themselves suspended in such a way as to oscillate. This method gives very good results.

The speed of the square cable should not be greater than 1 meter (3.28 feet) per second. If, as is desired, there will be an agreement to make experiments we can expect an important extension of funicular haulage.

PAPER BY MR. F. DE SCHRYVER AND MR. J. ZONE, OF BRUSSELS, CHIEF DIRECTOR AND ASSISTANT DIRECTOR OF THE INSTALLATION OF THE BRUSSELS MARITIME CANAL.

Since the congress at The Hague in 1894 there has been no important change in the mechanical traction on canals to bring to the attention of the present congress, but there has been much study given to the improvement of the existing means and to experiments upon new methods. In 1898 Messrs. Denèfle & Co. submitted a proposition to the Belgian Government to apply a method of electric traction. This is described in another paper by Mr. Chenu, so far as it relates to the canal from Brussels to Chaleroi. The authors describe the system proposed on the canal from Brussels to Rupel. The present canal is to be enlarged from an ordinary canal to a maritime canal. The present canal is 3.10 meters (10.17 feet) deep, 33 meters (108.27 feet) mean width, with five locks and with a length of 28 kilometers (17.38 miles). The new canal will be 6.50 meters (21.33 feet) deep, 20 meters (65.62 feet) wide at the bottom, and 56 meters (183.63 feet) at the surface of the water with four locks, 114 meters (373.92 feet) long, and 16 meters (52.49 feet) wide. By means of the Chaleroi canal and its branches the navigation extends to the industrial centers, and there is a movement of 24,000 boats per annum, carrying 1,600,000 tons. It is expected that when the maritime canal has been completed the business will reach 2,000,000 tons.

The authors describe the present means of navigation by chain towage, carried on by a company called the Towage Company from Brussels to the Escaut (Scheldt). The speed on this canal at present is about 5 kilometers (3.2 miles) per hour. There is given the full details of the law under which the company performs the service, together with the rates of toll and the expenses. It does its work by means of trains of from 6 to 12 boats, with a total load generally of about 900 tons.

They also give detailed information in regard to the method of traction. The chain is made of iron links from 0.11 meter (0.36 foot) to 0.22 meter (0.72 foot) long and 0.018 meter (0.06 foot) in diameter. The weight per meter is 6 kilograms (13.23 pounds). The total weight is about 170,000 kilograms (374,780 pounds). The chain lasts about eight years. The links lengthen in passing over the drum on the boat

The towing boats have a force of 15 horsepower and cost about 35,000 francs ($6,755) each.

The new systems proposed are described as follows: The dimensions and locks have been given above already. The banks will be protected by stone masonry, permitting a much more rapid speed. Bridges will be raised and many hindrances which now exist will be removed. A port comprising a maritime basin with an area of 12 hectares (29.65

acres) will be established at Brussels and a passing basin of 15 hectares (37.07 acres) at Laeken, 2 kilometers (1.24 miles) below the Brussels basin. Between these two basins it will be necessary to stop the chain towage and introduce some other system. The question has been studied by Siemens and Halske, of Berlin, and by Denèfle & Co., of Paris.

The former have proposed three methods by electric traction—electric towage by chain, electric towing by screw, and electric haulage by small rack locomotive. The first method will not differ from the present method of towage by steam except to replace the steam engine by electric motors of the same power, taking the current from an aerial line placed along the canal. The main electric station will be established at Brussels. The main electric carrying line will be of the three-phase system at low tension as developed at the central station for operating the plant at the port. This will be transformed to a tension of 10,000 volts and carried along the canal on three wires of 4 millimeters (0.16 inch) in diameter. Three other wires, 8 millimeters (0.31 inch) in diameter, placed on special insulators, will furnish the electric current to the towers with a tension of 550 volts. The line will be protected against fire at points of contact, and each wire will be provided with four interrupters, so that in case of damage to one wire it can be put out of circuit without interrupting the rest of the line. The current will be carried to the boat by means of a hauling cable attached at the stern of the tower to a mast about six meters (19.68 feet) high, which can be lowered in meeting other boats. Estimates are given for the cost of installing the plant and also the cost of operation.

For a traffic of 1,000,000 tons the plant will cost 425,000 francs ($82,025), and the operation per annum 77,788 francs ($15,013.08). If the rate per ton is fixed at 0.003 franc per kilometric ton (1 mill per ton mile), the traffic would pay 5.06 per cent. on the capital. With a traffic of 2,000,000 tons and the cost of plant and operation correspondingly increased, the same rate would pay 9.73 per cent.

The second method, by an electric screw, would take its electric current by the same installation, but the cost of operation would be less, and at the same rate as by the other method it would pay 9.7 per cent on 1,000,000 tons and 16.2 per cent on 2,000,000 tons.

The third method, by rack locomotives: It is proposed to establish along the towing path of the canal a light railroad of a special system on which will move a locomotive weighing about 1,500 kilograms (3,307.50 pounds) and with 15 horsepower; this small power being supplemented by additional locomotives when necessary. The Prussian Government has asked this company to make a series of experiments on the Finow Canal on a length of 1 kilometer (0.62 mile) for several months. The expense of the first installation is quite large, but the cost of operation is very much reduced below other systems.

The cost per kilometric ton being for 1,000,000 tons traffic 0.0025 franc (0.9 mill per ton mile).

Messrs. Denèfle & Co. propose a system by electric horses, using towers between the two basins already described. These towers will operate by petroleum gas motors of 25 horsepower. On the canalized Dendre price of towage by this method is about 0.003 francs (1 mill per ton mile). The authors do not think that it is of use to draw any conclusions at present upon the various systems proposed, but to wait for the results of the experiments which are now being made.

PAPER BY MESSRS. LA RIVIERE AND BOURGUIN, CHIEF ENGINEERS OF PONTS ET CHAUSSÉES, OF FRANCE.

The Sixth Navigation Congress, held at The Hague in 1894 decided that the questions on mechanical traction along canals that had been submitted at the Paris Congress in 1892 needed still further investigation and experiment. The investigations recommended by both of these congresses were further experiments upon resistance of boats to traction; the study of the twisting of the cable in funicular haulage and experiments on electric towage; also the study of the economic organization of traction. Mr. De Mas will give an account to the first section of this congress (previously described) of his experiments on the resistance to the movement of boats and the very practical conclusions to which he arrived. We will give an account of the improvements made or proposed in reference to mechanical traction on interior navigation upon canals since The Hague Congress. Our paper will relate more especially to France, where the system of navigable waterways offers special advantages for experiment, leaving to other writers to give an account of what has happened in other countries. We will first give the situation as it was in 1894, and then a general résumé of of what has been done since in France.

First. Conditions in 1894, general review of progress since.

Systems experimented on before the Congress of the Hague can be placed under three divisions.

1. Replacing horses by locomotives moving on the towpath.

2. Employment of an endless cable placed along the banks and to which the boats can be attached, or funicular haulage.

3. Placing upon each boat a motor of some kind which can be easily detached, serving successively the requirements of boats going up and down the canal.

As to the first division, the haulage by locomotive was suspended after a trial of several years on the canals d'Aire and La Deule. Its failure was attributed to the excessive expense of building a railroad on the towpath, and otherwise by the irrational method of using such

a machine for the very low speed. Since The Hague Congress there has appeared the electric horse of Dr. Galliott (already described in the previous paper), also an account of the formation of a company for electric traction by Messrs. Denèfle & Co. (also described previously).

As to the second division, that of funicular haulage, extended experiments were made on the canal of Saint-Maurice by Mr. Levy (described in a previous paper as employed on the tunnel of Mont-de-Billy).

As to the third division, comprising electric towage, particularly by a magnetized pulley, experiments have been made by Mr. De Bovet on the canal Saint-Denis (already referred to in a previous paper and to be described by Mr. De Bovet in a subsequent paper).

Second. Funicular haulage.

This is illustrated by description of the installation in the tunnel of Mont-de-Billy. This is illustrated in considerable detail on Plan I (No. 18). The writers go into full details of the mechanical methods as well as the costs. As the subject has already been fully described, it is unnecessary to give a further résumé of these details.

Third. Electric towage.

Experiments upon the canal Saint-Denis. This description relates again to Mr. De Bovet's plan which is described in his own paper.

Fourth. Electric propeller.

On Plan II (No. 19) is given the detail of an apparatus proposed by Mr. Galliot and already described.

Fifth. Electric horse.

This has already been described in a previous paper, but a different illustration is given in the present paper on Plan II (No. 19).

Sixth. Experiments by propeller and electric horse on Canal Bourgogne.

These experiments have been previously described in reference to the canal at Dijon, by Messrs. Denèfle & Co.

Seventh. Electric installation on the canals d'Aire and la Deule in a distance of 26 kilometers (16.16 miles).

The authors go into a full detail of the law under which the experiments were made, the bases of the installation, a description of the electric line, the cost of the installation and of the operation, and the results of the experiments, all of which have been previously referred to in other papers.

Eighth. The economic organization of electric traction on a section of 50 kilometers (31.07 miles), of a canal with a double towpath and for the purpose of realizing the full capacity of traffic. *The selection of the motive power.*

The writers discuss the results and compare the methods arrived at by various experimenters on canals of various amounts of traffic, and in conclusion after making full comparisons and costs, they are of the

opinion that the divergence in results necessitates a further study of the mechanism of different systems of traction and of placing the results together in such a way as to be comparable and from which to deduce the best method and the most valuable.

Ninth. Conclusions.

First. Special conditions of transit where, as in tunnels, for instance, on summit levels, the towpath is restricted in width for the use of horses and where, for a long time, it has been recognized that mechanical traction ought to be adopted whenever the traffic attains sufficient importance, and where, for instance, it is necessary to make the movement by means of convoys. For such places electric towage, or funicular towage, has already given excellent results.

Second. Traction in ordinary canal.—The operation here by convoy is no longer admissible. The boats should move separately; then it would seem to be better to place the motive force so that it can be easily and quickly attached and detached; by a moving cable the boats can be connected at any point whatever, and the same may be said of electric towage, where the power by a wire extends the length of the canal. The writers are strongly of the opinion that the governments of the countries where the experiments are to be made, and where it is proposed to introduce the actual service, should assist and give reasonable concessions, otherwise the large cost of making large installations prohibits the carrying out of experiments on a large scale, and they propose to the congress the examination of this subject.

PAPER BY MR. A. DE BOVET, OF FRANCE, DIRECTOR OF THE TOWAGE COMPANY OF THE LOWER SEINE AND THE OISE.

The subject of this special paper is individual towage of canal boats. He considers it unnecessary to go into the questions which have already been taken up in other congresses in reference to the utility of mechanical traction and a realization of this method. The substitution of mechanical traction by some method in place of animal traction would be of great advantage. As canals generally have a number of locks unequally distributed and of such dimensions that often only one boat at a time can enter, the methods by mechanical traction require that the movement of the boats should be subject to the captain of each boat. This condition makes the solution difficult; consequently there has been a large number of systems proposed, some of which have been condemned and others ought to be, and some appear to merit retention and development. These latter can be arranged in two grand divisions.

1. Those where the necessary power is produced by as many machines as there are boats to haul.

2. Those where the power is produced in a small number of plants and distributed to the boats as they move. To the first division belong all those methods of traction where steam locomotives are used, moving on rails. Various attempts to utilize this method have not been successful. In this same division should be placed boats which would have a propeller actuated by a gas motor, and which would have some means in various parts of their course to renew the compressed gas. The success of these various methods appears to be very doubtful, first, on account of the cost of maintaining banks of canals; second, on account of the necessity of keeping up the steam at times of long delay required for the loading and unloading of the boat, and for other causes, and finally, it must be considered that on a network of navigable waterways, such as exist in France, a boat can not move over a long course without passing through canals and through rivers, so that a motor suitable for propelling upon the river would be unsuitable for the canal, and vice versa. In the second division are found all those systems which require the employment of funicular cable, of which descriptions have been fully given in preceding congresses, and also the distribution of electric force by numerous mechanisms, of which each uses only a small quantity of this electric force.

Second. In a report to the Paris Congress in 1892 the writer gave a description of a system under the above second division; and at The Hague Congress in 1894, during a discussion, he gave some information in regard to an apparatus then in construction with a view to experiment. Those experiments have now been made and the results are stated. The method consists principally in making each boat an automotor by giving it during its progress through the canal an apparatus by which there is a magnetized connection made with a sunken chain, and receiving its electric energy from a current taken from electric lines placed along the banks of the canal. On Plan I (No. 20), in figures 1, 2, and 3, the general plan of the system as applied to a canal boat is shown, the current being taken laterally by means of a trolley moving along the electric line. The towage apparatus, which is placed in a box on the side of the boat, is shown in figures 4, 5, and 6 on plan (No. 21). Experiments by this method were made on a loaded boat of 300 tons, December, 1894, on the Canal Saint-Denis, in a length of 400 meters (1,312 feet), on a line with 110 volts. One convenient feature of this method is that the boat steers very evenly in spite of the traction of the chain, and it can, at the will of the boatman, approach the bank along which the chain has been placed.

Third. In addition to a description of the towage apparatus itself, the writer gives some facts upon other parts of the installation. The electric-power stations present no special feature; they can be placed along the canal and can utilize any fall of water that is available within a convenient distance, and hydraulic or steam motors can be used.

Fourth. The experiments have been so successful that the writer considers it now necessary to make a definite application, and another application by another series of experiments upon a large scale to prove the advantages of the operation, especially where quite a number of boats can move simultaneously both ways and during a sufficiently long time. The author has arranged for such a test of the system on a canal in the north of France. The plan embraces the installation of a line about 6 kilometers (3.72 miles) in length, and susceptible, in case of successful results—of which he has no doubt—of being extended the whole length of the canal, and ultimately to other canals connected with it.

Fifth. The writer's purpose is to furnish the congress with information on a definite system. He hopes that experiments upon other systems will be carried out to their full length practically and the information given, so that they can be properly compared. He suggests a maximum speed of boat of 3 kilometers (1.86 miles) per hour, considering that whatever may be the method employed it is not economical to exceed this speed. In reference to the cost of the rates of haulage, they are very variable, according to the season and the region where the traffic is, or whether the haulage is without tolls. These costs attain a minimum in France on waterways of a great traffic, and it is only under such conditions that mechanical traction can expect to be successful. This minimum cost or rate is 3 millimeters per kilometric ton (one-tenth cent per ton mile). He considers that even with that very low rate mechanical haulage of the best systems ought to be able to do the work 15 per cent less.

NOTE.—The details of an endless screw and of the special gearing are shown on Plan I (No. 20), figs. 7, 8, 9, and 10. The trolley is shown on Plan II (No. 21), fig. 11.

SECOND SECTION.

Second question.—Single lock-gates, rising, rolling, pivoting, or falling gates.

PAPER BY MR. L. PIROT, OF BELGIUM, CHIEF ENGINEER AND DIRECTOR OF PONTS ET CHAUSSÉES.

Introduction.—The canalization of the Belgium Meuse has given rise to the employment of barrages of various systems by frames and needles of the system of Poirée in the lower river from Vise to Namur. The Government in 1886 adopted for the river above Namur the system Chanoine by the use of raising planks. The author gives some objections to the use of these various systems and then describes an invention by Mr. Maus, inspector-general of the Ponts et Chaussées, who was

the president of a commission for suggesting a different system. The plan designed by him was called the articulated barrage; a model on a reduced scale was operated by water taken from the Charleroi Canal at Brussels. This experiment showed that this barrage would work under good conditions, but as the model was worked under only about 0.40 meter (1.35 feet) head, it remained to be seen if it would work on a river, where there would, of course, be much greater head. The author then goes into considerable detail describing this system, of which the following is a brief résumé:

The author gives the name of barrage "soufflet" (rising). Plan I (No. 22) shows in full line the position of a barrage when raised, and in dotted line its position when lying down.

The author states that one section of a barrage or a lock can be provided with this special appliance to a considerable advantage; that there are two objects to be gained, one in case of an accident to the lower gate. The articulated barrage can then be raised and the chamber of the lock filled with water from above, or it could easily be arranged to produce a flow of water so that a boat can be forced out of the lock in going down the stream. While this method might have inconveniences for ordinary locks, the author believes that it would be of interest to engineers to study the plan to adopt under special conditions.

PAPER BY MESSRS. LA RIVIERE AND BARBET, CHIEF ENGINEERS, PONTS ET CHAUSSÉES, AT LILLE AND EPINAL, FRANCE.

Note by the editor.—These writers, in a lengthy paper covering about 24 printed pages, have discussed the four methods of single lock-gates embraced in the question and have given many details of value, formulæ, etc., which can not well be embraced in a résumé.

I. *Introduction.*—The writers state that they were instructed to present the whole subject to the congress, embracing the four kinds of gates, but they do not propose to dwell at length, except upon pivoting gates.

II. *Falling gates.*—This kind of a gate, which the writers consider is only to be found in actual use on the Erie Canal in the United States, consists of a single leaf or gate turning over on a horizontal axis placed on a sill of the lock. The gate, which is built of wood, becomes buoyant in the water, and is worked very easily by means of a chain operated by gearing and a hand wheel. When it is in its upper position it is a little off the vertical, so that it falls by its own weight. The first idea is simple and practicable; the complicated conditions of other gates, especially of hollow quoins, disappear, and economy in the masonry is possible, and the method presents most of the advantages

which pivotal gates of one leaf present. On the other hand, the axis of rotation, which is entirely under the water, can not be examined, and muddy deposits which tend to form there interfere with the bottom on which the gate rests.

III. *Rolling gates.*—There are briefly described gates of this kind which were built about fifteen years ago at Davis Island on the Ohio River, United States. Such gates are rolling caissons, also employed in England for separating two harbor basins, when it is necessary to lower the surface of the water in one of them. The gate can be drawn either one way or the other by hydraulic power or by means of chains worked by a turbine. The gate in opening moves into a chamber built in the side of the lock; when it is shut, it runs into a recess on the opposite side and is held there by a rabbet in the side wall of the lock.

This type of gates is advantageous in lock chambers of great width, but the authors do not think them useful in ordinary locks of only 5 or 6 meters (16.40 or 19.68 feet), except perhaps in case of very large differences of level, or where it is necessary to reduce the length of side walls. This method requires the construction of a special chamber in the "terreplein," and has the inconveniences also that attach to falling gates—that is, the difficulty of removing the mud which is deposited in the chamber and on the rails; also, it is impossible to oil the axles of the wheels, which are always under water.

IV. *Rising gates.*—This method, which is rarely used on ordinary canals, becomes advantageous on large canals where there is a very considerable elevation to be made. Therefore the writers only describe in a summary manner the gates of this kind built at different times—as on the Western Canal, Taunton, England, and at Anderton, Manchester, at Fontinettes in France, and at La Louviere in Belgium. These various installations are so well known that a detailed description is unnecessary in this résumé. However, the designs of the gates at Fontinettes are shown in Plan I (No. 24).

V. *Pivotal gates.*—Comparison of single gates and those with double doors or leaves. The closing of locks up to the present time has most generally been made by double doors, but in recent years the tendency is to replace them by single gates, and the method has been adopted in the United States and also in France on certain interior canals and for maritime locks up to 16 meters (52.49 feet) and even to 24 meters (78.74 feet) in width. The advantages of single gates on interior canals were discussed for the first time by three prominent French engineers, Messrs. Nicou, Flamant, and Quinette de Rochemont, all at present general inspectors of the Ponts et Chaussées. (See their reports of July 12 and December 10 and 15, 1882, in reference to projected locks on the Northern Canal and upon the canal joining the Escaut and la Meuse.) Since that time this system has been applied

in France to the Saint-Denis Canal and to the derivation of the Scarpe around Douai. The maneuvering of the single gates is more simple than that of double gates. It does away with several causes of wear and tear. Adjustment and repairs are more easily made, and especially there is less loss of water. Often there is at a lock only one man, and where there are double gates one of them must be handled by an assistant, who is generally one of the boatmen. This practice is objectionable, because it brings in a stranger who does not understand the handling of the machinery, and the tendency is for the two gates not to come together at the same time, causing them often to be jammed, or to leave a slight opening; or, if force is put upon the gearing, to bring them closer together, under such conditions there is often a wrenching and distortion of the gate. Then, again, the replacement or repair of one of the double gates requires, generally, to take the water out of the lock and consequently to delay the navigation several days. A single gate does not have these inconveniences. The filtration through the gate is very much less, for the gate is pressed directly by pressure of the water against the frame and shoulders upon which it rests. If necessary to replace one, it can be done in a few hours without serious delays in navigation. Its construction also is relatively easy, consequently is more economic, and if it requires a lengthening of the lock over that where the double gates are used, the extra expense involved is less than the cost of the complicated apparatus and the hollow quoins required by the double gates. The authors now describe single-lock gates at three locations. First, on the canal Saint-Denis, which are built with a metallic frame, covered with wood, and calked. The details of the gate are shown on Plate I (No. 24), figures 4, 5, and 6.

Gates on the Scarpe, near Douai. Traffic on this canal exceeds 3,000,000 tons per annum. The locks have single gates, an iron framework, covered with wood. They are shown in detail on Plan II (No. 25). They are similar to the double gates, as far as materials are concerned, used in the lock at Ablon on the upper Seine, and according to the type in use for fifteen years on the navigable waterways of the north of France and the canal leading to Calais.

Gates on the canal adjoining the Escaut and the Meuse, already spoken of as having been designed by the three French engineers, Nicou, Flamant, and Rochemont. They have an opening of 5.20 meters (17.06 feet), with a fall of 4 meters (13.12 feet). They are made of galvanized sheet iron.

Maneuvering of lock gates.—In the case of double gates this is done by means of the lever arm formed of the upper traverse, which is extended so that the lock keeper can act directly upon it or by the aid of straight racks or of toothed arcs actuated by jacks. These same methods can be applied to single gates. The writer, however, recom-

mends a mechanical apparatus instead of hand movement, as the operations are much more regular and rapid.

Compressed air apparatus.—In studying the best method of operating the gates on the Northern Canal, the problem was given to Cail & Co. and to the Fives-Lille Company. The apparatus designed for a simple lock was as follows: Two accumulators, two apparatus for maneuvering the gates and four for maneuvering the valves, and the passageways for the distribution of water under pressure in pipes and the return pressure. The accumulator, like that at the elevator of Fontinettes, is actuated by the head of water at the lock. The writer goes into a lengthy description of this method. The entire apparatus is placed in chambers and is nowhere exposed. These chambers are in the side wall of the lock.

Apparatus moved by turbine.—They are found at the lock gates in the Scarpe navigation near Douai, also in the canal St. Denis. The apparatus is simple, strong, and gives excellent results, both in regularity and rapidity of movement. A turbine on a vertical shaft is placed at the lower end of the side wall common to the two chambers, and actuates a horizontal shaft which extends to the upper end of the side wall and puts in movement there, by the use of transverse shafts, the racks laid out on a circle for handling the gates. The turbine is about 6 horsepower, and makes 100 turns per minute. Its diameter is 0.878 meter (2.88 feet). The total cost of all the apparatus for one lock is about 23,000 francs ($4,439).

Hand apparatus.—There are various kinds of movements made by hand, but all of them transmit to the gate, by means of gearing and a crank, with a power more or less multiplied, the necessary effort, according to the resistance to be overcome.

One of the objections urged against the single-gate plan is the difficulty and the slowness of maneuvering it by hand on account of the large surface and the weight of the gate to be moved. Experience, however, proves that this criticism is not well founded, for there has existed for many years in Belgium, France, and America numerous double gates maneuvered by hand, of which the dimensions are equal to those of single gates described in this paper. The writers give a table of various locks with single and double gates, which shows that the immersed surface of the single gates which they have described is about 17.2 square meters (182.99 square feet). That of the double gates of the Erie Canal is 18.562 square meters (199.77 square feet). On the Saone there are four locks, 16 meters (52.49 feet) opening. The waters go into a long discussion, and give formulæ to show the weights and movements of gates.

Calculation of the dimensions of lock gates.—These calculations and dimensions assume that the gates have a metallic framework and a covering of wood. They refer to a rule laid down by Inspector-

General Guillemain annunciated by him in the school of Ponts et Chaussées, as follows:

A lock gate, rigid in every direction and in every sense, under the action of water undergoes the minimum flexure or distortion when the resistance is accumulated above and toward the middle of the pressed surface.

Choice of materials.—Formerly wood was more common, and the price of iron, and especially steel, was very high. The opposite condition exists to-day. Plates and bars of iron, and even steel, are made at a very low cost almost everywhere, and wood is becoming more and more scarce. The dimensions of gates have increased with the increasing size of chambers and the heads of water. Iron or steel, when it is maintained with care, is susceptible of a long life, and it is not doubtful that metallic gates may be renewed much less frequently than wooden gates. The general stiffness of the gate is assured when, all the parts being solid, it resists, so to speak, as a single piece, and can in consequence submit to strains in all points and in every sense without making any sensible deformation. This stiffness, not only in point of view of maintenance and of handling, is much greater with metal than with wood. In the case of wooden gates, the weak points are the framing and the decay to which the material is exposed there; in metallic gates, on the contrary, the framing can be made the most solid part of the work. In fine, metal allows of concentrating the required resistance in a small number of pieces, and thus secures a reduction of weight, leading to economy in construction and great facility in handling. This can not be said of wood. These considerations apply to the framework of the gate, but the covering of wood is much more suitable. If a metallic covering is cut through, or has to submit to shocks, its repair is difficult. Another advantage in the use of steel in the framework of gates arises from the fact that the shapes for the bars and sheets, both in steel and iron, are easily found.

VI. *Conclusions.*—1. Tumbling or falling gates have the same essential advantages of pivotal gates of one leaf, but they are not recommended, as the machinery is always under water and consequently can not be easily examined.

2. Rolling gates reduce the length of the side walls. On the other hand, they require the construction of a special chamber for receiving them, which has the same inconvenience as the falling gates. They appear to be most useful for closing chambers of great widths, but should not be used on ordinary canals, except where there is a great head of water.

3. Lifting gates have the general advantages of single gates, and also have economy of masonry, like rolling gates, without having the inconveniences of falling gates. On the other hand the apparatus for

maneuvering them is cumbersome and costly. This method should be reserved for lifts.

4. Pivotal gates for single-leaf gates are recommended to the attention of engineers. In spite of the increased length of lock required by them they are not more costly than double gates. They yield less to fatigue, permit less loss of water, are more easily adjusted, repaired, and replaced; their maneuvering is more simple and more regular.

5. The selection of a system of single-lock gates does not necessarily require a mechanical installation. They can be maneuvered by hand, and by one man, without excessive effort, and within admissible time.

6. Mechanical apparatus with compressed air, or turbines and transmission by gearing actuated by a fall of water at the lock, is justified upon canals of large traffic, and the service which it renders is not out of proportion with the relatively high price of the apparatus.

7. Iron or steel is preferable to wood for the framework of the gate, particularly for gates of large dimensions, on account of the reduction in expense, the duration, the solidity of the framing, and the general stiffness of the gate. On the other hand, wood is better for the covering. It can be more easily repaired and replaced.

8. Steel is preferable to iron. It allows a great reduction of weight, to the great advantage of the maneuvering, an economy which the writers think is not less than 15 per cent of the total cost of the gate.

In addition to the plans already referred to, see Plan III (No. 26) for a project of the single gate in the junction canal of the Escaut and the Meuse.

PAPER FROM THE ROYAL HUNGARIAN DEPARTMENT OF AGRICULTURE, SUBMITTED BY THE BUREAU OF WATERWAYS.

ROLLING GATE OF THE LOCK AT D'O-BECSE (HUNGARY).

NOTE BY THE EDITOR.—As this lock gate is of exceptional size and operated under peculiar conditions, it is described somewhat at length.

The Francis Canal connects the Danube at Bezdan with the River Tisza at Bacs-Foldvar (see the general map (No. 27)). Its construction was begun in 1794 and was completed in 1801. At that time the improvement of the Hungarian rivers had not been made. Both the rivers above mentioned were in their primitive condition and the boats were obliged to follow the winding of the channels. Afterwards correcting works were begun and many of the curves of both rivers were cut off, specially on the Tisza. These cut-offs now form a main channel and the curves cut off have silted up. The great curve of the Tisza received at Bacs-Foldvar (see plan of the outlet of canal) the waters of the Francis Canal, and this also silted up after the cut-off was made, so that boats were navigated with great difficulty and con-

stant dredging was required. For these and other reasons the outlet of the canal was changed to O-Becse, where there was a city of some size and where a railroad connection could be made for the canal navigation. This required the construction of a canal of extension 8 kilometers (4.97 miles) long, and the building of a new lock (see the general map, Plan I (No. 27)), to which also the above references are made.

The new canal is shown by letters of A and C, and by letter B, which shows the embankments 600 meters (1,968 feet) long, which protect the country from the overflows of the Tisza. These embankments are 100 meters (328 feet) apart, and form a convenient winter port. The new works, therefore, not only correct the conditions at the entrance of the canal, but form a winter port, of which there are none along the entire course of the Tisza. It was necessary to build a lock gate that would serve the purposes of the largest boats on the river. It had to be 16 meters (52.49 feet) wide, 2.5 meters (8.20 feet) deep, and 70 meters (229.66 feet) long. The regimen of the waters made the conditions very complicated. It was necessary to preserve in the new canal the level of water in the old canal, otherwise the level, 40 kilometers (24.85 miles) long, which extended into the new canal, would have to be changed entirely to conform to the new conditions. It would, of course, be very expensive. Again, it was necessary to allow for the variation between the maximum and minimum heights of water in the river, about 9 meters (29.53 feet). The level of water in the canal stands at 7.1 meters (23.29 feet) above the level of low water in the Tisza, and it is 1.75 meters (5.74 feet) below the level of the water at high river. These data show that the canal gate must sustain pressures in two directions equal to the above figures. This condition required that the lock should be divided into two chambers, each 70 meters (229.66 feet) long. Rolling gates of iron of a special construction were designed.

At first thought it would seem that gates with two leaves would be best to offset the double pressure, and that extra gates should be put in to meet the conditions; but this plan could not be adopted for the reason that the foundations of the walls of the chamber were laid in small stone, and the building of the contragates would require a large extra expense. The writer of the paper considers that, taking into account the dimensions and the apparatus, which are in every way modern, these gates unequaled in interior navigation. The larger gate alone is described. Its length is 16.96 meters (55.63 feet), its height 9.17 meters (30.08 feet), and its thickness 1.65 meters (5.41 feet). The framework is formed of 4 upright posts and 3 cross girders. Two of the former and 2 of the latter constitute the frame. The two other uprights extend upward the two sides of the gate, and a third cross girder is placed above the gate. Between these principal parts there

is a network of secondary upright posts and cross girders. All this framework forms a latticed chamber.

The covering of the gate is made of iron plates and is put only upon the canal side. Its thickness is 8 to 12 millimeters (0.32 to 0.47 inch). It is fastened to the frame in such a manner as to sustain the pressure coming from both directions. Joints are carefully riveted. The parts also form dry chambers filled with air, which lighten the gate and facilitate the movements. Any water that penetrates into the chambers is pumped out by hand. The vertical parts of the chambers are supplied with steps, so that the interior can be examined.

The gate does not roll on the foundation as is usually the case; it is suspended from a sort of a car which moves upon a bridge above resting on iron piers. The suspension of the gate is made by the aid of 8 frames which extend above the gate; each of these frames is extended by wide strips of iron which converge above and are riveted to the beam placed immediately under the car. It will be seen that this is a sort of pendulum system, allowing of slight oscillations forward and backward. By this means the gate can be shut whether the pressure comes from the canal or from the river. A description is given of the method of placing the bearing surfaces between the gate and the walls so as to make it water-tight. A car is provided with 8 wheels with steel axles; the bridge and piers weigh 53 tons; the total movable weight of the gate with the suspending apparatus, the passage ways, and the sluice valves is 150 tons, but as the gate is lightened when submerged to the extent of 44 tons, the weight of the gate to be moved is then reduced to 106 tons.

Of course it would be expected that such a weight could not be moved by hand. Electric energy is furnished by a dynamo and a turbine, the latter being actuated by the motive force of the water in the level. The electric current is transmitted to the car by a secondary dynamo. By this means the car moves the gate in three minutes. When the river rises the pressure is less, and then the car is moved by hand by detaching the dynamo and putting the gate in movement by chains, which are handled in the passageway above the gate. Under these conditions the gate is moved in twelve minutes. The gate moves into recesses. There are side rollers moving on rails entered into the recess. Balls of cork are placed in the recess to lessen the shock. The filling and emptying of the lock is made by four sluice gates of venetian blinds, having a total opening of 5 square meters (53.82 square feet). Three minutes are required to open these sluice valves. The larger gate above described cost, with the bridge and apparatus complete, 77,034 florins ($36,976.32); the smaller gate, 60,217 florins ($28,898.16). The total expense for the lock, exclusive of the gates, was 771,000 florins ($370,080), with 280,190 florins ($134,491.20) for

building a winter port and a new canal, the total expense for all works being 1,312,390 florins ($629,947.20).

Work was begun in September, 1895. At the time of writing the paper the new canal and lock were finished. The gates were to be mounted during 1898. In the spring of 1899 this important work, which the writer considers remarkable in regard to its dimensions and construction and the system adopted, will be opened for traffic.

For details see Plans II and III (Nos. 28 and 29).

PAPER BY MR. A. DEKING-DURA, OF THE NETHERLANDS WATERSTAAT OF OVERYSSEL.

The writer's descriptions relate to turning and rising gates of one leaf existing in the province of Overyssel.

A. *Turning gates*—There are four of one leaf in this province, from 3.05 meters (10 feet) to 7 meters (22.97 feet) in width. The reasons for adopting a single-gate type are as follows:

1. An economy of considerable importance.

2. The lock keeper is able to handle the gates, and is not obliged, as in the case of double gates, to either maneuver the second gate by a boatman or to lose his own time by crossing over the canal and handling the second gate himself.

3. The works at the head of the lock, the sill and foundation, are of very simple form. On Plan I (No. 30) is shown the head of a lock built in 1894 at Lichtmis, on the Dedemsvaart canal. The lower head of the lock is provided with ordinary double gates for some special reasons which the writer gives. The width of the lock is 6 meters (19.68 feet); the canal has a depth of 1.80 meters (5.91 feet), and there is a head of water of about 2 meters (6.56 feet). It would have been an incorrect plan to have built such a gate of wood, the total width of which is 6.625 meters (21.73 feet); it is therefore built of iron.

The plan consists of a framework of beams, this frame weighing 47.9 kilograms (105.6 pounds) per meter, with a covering of galvanized-iron plates. The turning post is reinforced by a second beam, weighing 33.5 kilograms (73.86 pounds) per meter. The plates being riveted closely, the one to the other, and upon the crossbars and uprights, assures the perfect rigidity of the whole gate; also that it will not pull away from its fastenings, as would be the case if built of wood. The writer then describes the method of making the gate water-tight by means of wooden furring strips and vegetal tarred paper. The sluice gate covers an opening of 2.87 meters (9.31 feet) and is also made of galvanized sheet iron stiffened by corner plates, and is moved by a tooth rack by means of windlass shown on the plan. This movement is facilitated by a counterweight. The gate is handled by means

of a tooth rack which is placed above the gate, and it engages in a tooth wheel installed or placed on the side walls. The drawing shows this method. The form and the arrangement of the head of the lock generally is shown on the plan. The total weight of the gate is 3,350 kilograms (7,385.40 pounds). This lock was opened for traffic in 1894 and has never given any trouble. It is perfectly water-tight, and experience upon three other gates of the same type is equally satisfactory. The cost of the lock, gate, and apparatus above described was 11,991 francs ($2,314.26).

B. *Rising gates.*—In the province of Overyssel this kind of a gate is used in only one navigation lock but there are four sluice locks where it is used. Although they do not directly serve navigation as yet, they are indispensable on many navigable canals. As far as the construction of the gates is concerned, it is similar to those used on a navigation lock, except that the height is greater. In the four gates above mentioned the rising or sluice gates are built according to the Stoney plan. The gate balanced by a counterweight bears during its movement upon rollers placed on the lower side. These rollers, suspended on the one side from the gate and on the other from the permanent parts of the locks, move through a distance one-half less than that of the height of the gate. Instead of slipping friction, it has to overcome only a rolling friction. Even under a great pressure of water it is not necessary to use more than a very slight effort to move the gate. All the locks mentioned are built on this general plan, but there are important differences in the secondary machinery. The gate is made of iron beams, and this makes a simple and economic construction. The author refers particularly to a discharge lock built in 1897 on the Coevorder Canal (shown on Plan II (No. 31)). The lock has two openings, each 6 meters (19.68 feet) in width. This is the general plan of such work in Holland as far as the lock itself is concerned. It rests upon a pile foundation, provided with three rows of sheet piles and a wall screen. It is built of masonry made of hard bricks. The cut stone is red granite from Norway. The openings between the beams placed on the upper side permit of the gates being examined. At the lower end of the lock the bed is protected against erosion by a bed of rock of a length of 20 meters (65.62 feet), the rock being basaltic column 0.25 meter (0.82 foot) in length. The gates are built of three latticed beams. The covering on the upstream side is of galvanized iron. At the two ends are placed cast pieces in the form of caissons. Gates are 6.50 meters (21.32 feet) wide. They move in grooves arranged in cast posts placed by anchorage in the masonry. There is allowed a play of 3 centimeters (1.18 inches).

The writer describes how the gate is made water-tight by means of a beveled surface of oak at the bottom against which the gate rests

and smoothed surfaces on the sides, and he describes the movement upon the rollers. Above the gate there is a bridge on the two posts on which are fixed platforms which carry a shaft, on which is suspended a gate with its counterweight; this shaft has a diameter of 8 centimeters (3.15 inches.) The gate is balanced as well as possible so as to maintain it always in a vertical position. The shaft spoken of above is rotated by a windlass, shown in the plan. The movement is very easy, as is proven from the fact that it is ordinarily made by a woman. The weight of the gates above described are 2,200 kilograms. (4,851 pounds). The counterweight is about the same. The whole weight, including the weight of chain, is about 4,600 kilograms (10,141 pounds). The cost of the lock was 28,350 francs ($5,471.55); 19,950 francs ($3,850.35) of it went into the construction of the lock comprising the protecting bed described, and 8,400 francs ($1,621.20) for the gates and their accessories. The paper is accompanied by Plans I and II (Nos. 30 and 31).

PAPER BY MR. E. F. DE HOERSCHELMANN, COUNCILOR OF STATE OF KIEFF, RUSSIA.

The paper relates entirely to navagation canals in Russia. The first example of a lock with one gate is that built on the canal Vychenevolotsky, designed by Engineer Koritzki. This gate was used to shut, not a lock with a chamber, but a simple sluice lock, called in Russia half a lock. The very peculiar gate described is shown on Plan II (No. 33). The navigable waterway under consideration is not, properly speaking, a lock canal in the ordinary sense of the word; it has no lock except at its summit level, which is a sort of reservoir to receive from other reservoirs into which the floods of the rivers are led and from which summit level the water is supplied through the rest of the navigation; it therefore forms a sort of chamber of a length of nearly a kilometer (0.62 mile). Navigation is made by convoys of several boats and by rafts of timber. On account of handling large masses of water with a very considerable navigation, it was necessary that the lock gate shutting the summit level should have great solidity, for in case of a breakage in this gate the boats and rafts would be forced into the canal and would break the lower gate and go adrift, causing serious accident; therefore, to give this gate an extraordinary solidity, the engineer designed a special construction. It is a single gate of the width of the sluiceway between the walls, and it is formed of three beds of squared timbers arranged in rectangular form. Between the first and second beds there is a plank partition; when the sluice is open this gate floats on the surface of the water. In order to shut the sluice the gate is placed in an inclined position and in this way sustains the pressure of the water in the sumit level. The plan referred to shows the method

of placing and supporting this gate and the detailed description is unnecessary. When it is desired to drop the gate, take it out of position, the rope I shown on the plan is slackened and the post C falls back upon its position, shown by dotted lines, against the two inclined supports. The intermediate timbers between this upright post and the gate also take the positions shown in the dotted lines.

Lock gates with one leaf are still found in Russia on the canal Tikhvinnski; they were built about a dozen years ago. This method was decided upon at a conference of engineers who were convened in 1885 for the purpose of designing a method to simplify the extremely complicated construction of double wooden gates. They decided upon gates with one leaf turning on an axis either horizontal or vertical. The paper gives full specifications in reference to the method of construction, under which there were built in 1885 and 1886 several locks on this canal, the single gate being used to replace double gates at the upper end of the locks. In 1886 a second conference of engineers was called to examine carefully the new constructions and to make a report. These gates are mostly wooden, and those upon the canal Tikhvinnski are shown on Plan I (No. 32), and illustrate the two methods—one by a horizontal axis and the other by a vertical. The advantages of a gate turning on a horizontal axis were considered greater than those with a vertical axis, particularly as they are less liable to serious accident.

Four or five years ago the question of the construction of lock gates of one leaf built of iron was taken up by Professor Timonoff, who proposed and designed such gates for the locks in the cataracts of the river Dnieper; the opening of these locks is about 15 meters (49.20 feet); the leaf turns on a vertical axis. On Plan II (No. 33) is shown a design of these gates, which are more fully described by Mr. Timonoff in his work on the cataracts of the Dnieper, written for the Sixth International Congress of Navigation, held at The Hague in 1894.

PAPER BY MR. SCHNAPP, OF THE MINISTRY OF PUBLIC WORKS, BERLIN.

In Germany the usual method of building canal lock gates is to use two leaves, and it is only until very recently, and then in isolated locations, that gates of one leaf have been built. An application of the principle of the falling gate was made on the canal joining the Oder and the Spree, built in about 1890. This canal has a depth of about 2 meters (6.56 feet). At the locks on this canal the lower gates are still of the double-leaf pattern, while at the upper end of the lock a single-leaf gate is built on the system employed in American locks. The arrangement is shown in detail on Plan I, figure 7 (No. 34). The

gate is built of pine wood; it has a width of 9 meters (29.52 feet) and a height of 3.27 meters (10.73 feet). This plan with full details is shown on sketch above referred to. One advantage of this construction is the lesser length than in locks with two gates.

The second system described by the author is that of a single rolling gate, which has been applied on a large navigation inaugurated on the Oder during last year. There is specially described the works on the new waterway around the city of Breslau, about 3½ kilometers (2.17 miles) in length. This canal had to employ a lock specially for the purpose of equalizing the difference of the level with that of the old Oder, where there was a needle barrage for the purpose of furnishing water to the canal. The river lands of the old Oder are very low, and in order to protect them against inundation by the floods of the Oder it was necessary to establish a guard lock in a dike. As the canal had also to serve the purpose of a winter harbor for boats, it was also necessary to prevent the waters of the canal going into the river in winter, and the gate therefore had to serve the purpose of sustaining two pressures. The sluiceway to be shut has 10 meters (32.80 feet) opening, with a maximum height of water of 7.20 meters (23.62 feet), and it had to resist a pressure of water of about 5 meters (16.40 feet) or more. According to the calculations, a double gate would have cost about 25 per cent more than a single gate shown in Plan II, figs. 1, 2, and 3 (No. 35), the project for which was fully elaborated by the architect of the Government, Mr. Braunlich, under the direction of Mr. Pescheck, director of hydraulic works. Differing from other existing structures, notably those at Bremerhaven and Kiel, where the gate moves on rollers, there was adopted for this gate the system designed by Mr. Eiffel for the Panama Canal, consisting of two cars suspended to a passageway above the lock and on which are placed rails extended laterally on the masonry. On the first car are placed two others, the rails supporting which are placed perpendicular to the first set of rails, consequently the gates can be moved in two directions and by this means there can be made a water-tight gate. The expense of the installation was about 130,000 marks ($31,200). This construction has the advantage of having all of its movable parts accessible at all times. The gate itself can be examined while in the recess of 3 meters (9.84 feet) wide, and can be repaired and repainted in all its parts, even when they are under the ordinary level of the water and even during the period of navigation, without interfering with the operation. It is not likely to be injured by passing boats; the maneuvering is easy and sure; even the cleaning of the hollow quoins on the foundation can be easily done. The calculation of the resistance of the different parts of the construction is simple and certain, and the use of the materials can be judicious and economic.

In closing the paper the writer refers briefly to a method of con-

struction of a rising gate, applied at a lift which is built on the Dortmund-Ems Canal, where boats are lifted 14 meters (45.92 feet), the maneuvering being based on the use of floats and screw guides. At the place referred to the sluice is 8.80 meters (28.86 feet) wide and about 3 meters (9.84 feet) height of water. A view of this gate is reproduced on Plan III (No. 36). The gate is balanced by counterweights, which stop automatically in case of a rupture of the cable. The maneuver is made by means of two rods working on a tooth ratchet to diminish the friction of the gates; in the slides rollers are used. The gate is provided throughout with an apparatus for lifting at the same time the gate of the movable chamber, which is also balanced by means of a counterweight.

As this work is still under construction a final report can not be made on the subject, nor can there be stated now the advantages or disadvantages of this construction.

Third question.—Means of securing the impermeability of the bed and banks of a canal. State in detail and fully the means suggested at the Paris Congress of 1892 in answer to the third question submitted to that congress, viz, the impermeability of canals.

PAPER BY MR. H. GENARD, CHIEF ENGINEER AND DIRECTOR OF PONTS ET CHAUSSÉES, BRUSSELS.

This paper gives details of the method employed to render impermeable different parts of the canal of Charleroi and of Mons now under construction, enlarging, and repairing.

Works executed for assuring the impermeability of the dikes.—Generally the leakages through the dikes have resulted from the inferior character of the earth of which they are built, or by want of good bonding between the embankments and the natural ground. Description is first given of works at Havre and on parts of the territory of Obourg, Nimy, and Mons. The filtrations to be stopped were due principally to want of union between the embankments and the soil, and in these embankments there have been built longitudinal diaphragms in good clay, not only from the top to the bottom of the dike, but often into the natural ground itself, usually 0.80 meter (2.62 feet) at the bottom, with a slope of 1 of base to 5 of height. (See fig. 1 (No. 37).) These cores are built in successive layers of 0.10 meter (0.33 foot) thickness, very strongly rammed. Such cores have been built to a depth of 5.50 meters (18.4 feet) and have given excellent results.

In the districts of Obourg and Nimy, where the dikes were formed of material not sufficiently clayey, the works consisted in rebuilding the slopes of the trunk of the canal on the water side, making compact revetments, as is shown on figure 3. These revetments had a thick-

ness of 0.70 meter (2.30 feet) on top and 1.60 meters (5.25 feet) at the bottom of the canal. Underneath these revetments there is placed a small core of clay, about one-half meter wide at the bottom and 1 meter deep with slopes 1 on 1. These works have not always given good results. It is very difficult to make the revetments compact, as one can the cores previously described. This method is not followed any more, except in case of stopping isolated leakages.

There is next described works to stop leakages under a dike built in embankment. These leakages were due to a number of small subterranean conduits resulting from the decay of roots of trees cut down many years before the building of the canal. These small conduits extend often entirely under the canal, discharging the water from the canal in a ditch on the opposite side of the dike. The trouble was obviated by building a very heavy reinforcement on the canal side of the embankment and using good clay, well rammed, and the foundation carried down 1.75 meters (5.74 feet) below the bottom of the canal. It is 0.50 meter (1.64 feet) wide at the bottom and about 4 meters (13.12 feet) wide at the top. All such works have given very good results. The conditions of several other points of the canal are then described, and the method of building new dikes. The ground is, in the first place, completely cleared of all vegetable matter, stone, gravel, brick, cinders, and waste matters of every description, and of roots also. In the latter case the extension of these roots is followed, and any conduits which may have been left by them are filled up by ramming into them pure clay. Underneath is prepared two longitudinal ditches, as shown in figure 6. They are 1 meter deep (3.28 feet) and 0.80 meter (2.62 feet) wide, and slopes of 1 to 1, and the center lines of the two ditches are placed 4 meters apart (13.12 feet). Materials of all these dikes are formed of pure clay, containing neither chalk, stone, gravel, nor cinders. The embankment is made in layers, and these are rolled by a hand roller, and also by a heavier roller, weighing about one-half a ton, drawn by horses. Works constructed as above described have not yet been tested, but as they are built of absolutely compact material it is thought that they will be impermeable.

Works executed for making impermeable the trunk of the canal.—On the Central Canal the permeability is due to the presence of chalky matters which are hard but full of fissures, and it has often been the case that the water let into the canal for operations disappears entirely with more or less rapidity, according to the permeable character of the chalk. There are two important conditions—first, where the trunk is not subjected to any subpressure; and, second, where it is subjected to such pressure. In the first case the work consists of forming a complete revetment of the entire trunk of the canal, both bottom and sides composed of cement béton of trass and covered by a thin layer of pure mortar of a thickness of 0.02 meter (0.07 foot). This

covering extends up to nearly the level of the water and it is continued to the top of the towpath by a stone revetment about a quarter of a meter in thickness. The details are fully given in figure 7. On the bottom of the canal this covering is only sufficiently deep to allow of a thickness of earth placed over it 0.30 meter (0.98 foot) thick. The béton is composed of 6 parts of small stones, either sandstone or porphyry, the pieces being small enough to pass a ring 0.03 meter (0.10 foot) in diameter, and 4 parts of mortar. These revetments are very successful. They were made in 1885, and have up to the present time required very small repairs. The second condition is where the trunk is subjected to subpressure. In this case there has been put on the bottom of the canal a heavier layer of the material.

Béton revetments on the slopes and the bottom of the canal when built of sand.—The works in this case are given in detail in figure 8. On the bottom of the canal there is laid a course of sandy clay half a meter thick, and the slope is built very much as described under the previous heading.

CONCLUSIONS.

(1) Works intended to assure the impermeability of dikes can not always be determined in advance upon theory; their nature and arrangement depend really upon local conditions found in each special case. The diaphragms or cores described in the paper are very effective, and are recommended. They can be executed, partially at least, without hindrance to navigation.

(2) It is important in constructing dikes to ascertain if there be any defects in the soil; and if so, to remove them. It is always more economic to do this than to be obliged to execute special works after the water is in the canal.

(3) In a case where the trunk of the canal is not subjected to any subpressure, béton revetments constitute very successful work, and the author recommends that this béton should be fully of the thickness shown on the plans—that is, 0.18 meter (0.59 foot)—covered with a mortar surface of 0.02 meter (0.07 foot).

(4) When there is sufficient or abundant water for the operation of the canal, and there is no reason for making the trunk of the canal absolutely water-tight, water charged with sediment gives good results if the permeable soil does not have fissures.

(5) Where the bottom is subjected to subpressure, béton, with a surface of mortar of the type indicated, should be used, placed on the slopes only, with a bed of fine and dirty sand placed over the fissured earth in the bottom. The thickness of this bed should be determined by taking into account the quantity of clay which the sand contains. If the canal water is strongly charged with mud, this thickness can be considerably reduced.

PAPER BY MR. E. LEFEBVRE, PRINCIPAL ENGINEER OF PONTS ET CHAUSSÉES, BRUSSELS.

The enlargement of the Charleroi Canal to Brussels and its branches required the building of various works for assuring the impermeability of the trunk and dikes of this navigable waterway. The author proposes to describe the systems employed. He considers the conditions important and exceptional, for the works are really upon a summit level about 89 kilometers (55.30 miles) long, with several branches uniting at the center of the great network of the Belgian system, the basins of the Meuse and the Scheldt, and rendering great service to commerce and industry. The feeding of this navigable waterway was done largely by natural means, but completed to the elevation required by an Archimedean screw from some small streams in the vicinity. The systems of works employed did not require the interruption of navigation.

The author proposes to describe the plans adopted for the new dike, and then to give the method of making old dikes on the canal impermeable, situated in the midst of numerous works of coal mines, which have caused, by their tunneling and mining, a pronounced settlement of the navigable waterway.

(1) *Enlargement of the branches.*

a. The building of new dikes.

These works were largely upon branches leading to coal mines. The nature of the soil of the whole region was very inferior. The land becomes very spongy under the action of water and also becomes fluid and soapy. The draft of water was to be increased to 2.40 meters (7.87 feet); this was done by raising the level of the surface of the water. In widening the canal the old line was maintained and so located as to make it necessary to enlarge only one side except in special cases. The works embraced the raising of the old dikes which were not displaced, and their reenforcement by embankments placed on the outside slope.

(2) The removal of the old dikes by cutting away the inside portion and building similar embankments, but more important than in the case of reinforcement.

(3) The building of an entire new dike 6 or 7 meters (19.68 or 22.96 feet) high.

These three methods of work present entirely different conditions in respect to the impermeability. In the first case the embankments placed on the outside slopes of the old dike would not be satisfactory if the old dikes were not themselves made tight. These old embankments have generally been leaky. The outside part has never been improved and there were old channels where the water filtered through. The subterranean work of earthworms and moles was often the cause of this by making a complete network of minute galleries underneath.

Another condition makes the dikes leaky. The trees, principally poplar and undergrowth of various kinds, had been cut down with care; but as it was practically impossible to get out all of the roots, they became after a while a veritable system of tubing, acting like drains to carry off the water, the roots decaying and leaving holes extending through the work.

In reference to entirely new works the conditions were more satisfactory. The soundings made showed that the navigable waterway would traverse soil of a clayey, sandy nature, generally of an inferior kind, composed of various kinds of soft and slippery clay. It was therefore decided to employ about 400,000 cubic meters (524,000 cubic yards) of earth obtained from the excavation, and to discard all marshy, muddy, and peaty soil. The dikes were to have a width of 7 meters (22.96 feet) at a point 0.75 meter (2.46 feet) below the surface of the water. The slope on the inside was to be of 7 base to 4 height, and the other slope 6 base to 4 height. In the first place, the land where the bank was to be built was cleared of all turf, vegetable earth, stumps and roots, stones—in fact, everything that was permeable. The land was then picked and worked over and cut in steps when it was on a slope, and then finally there were cut, lengthwise of the line of the dikes, excavations 1 meter (3.28 feet) deep by 1.50 meters (4.92 feet) wide, in order to cut off all holes of moles, or galleries caused by other means, which might exist under the surface of the ground. Embankment was then made of earth that was entirely freed from all perishable matter, the material being put on in layers of about one-fourth meter (0.82 foot) in thickness, extending entirely through the embankment. During the winter season it was necessary to see that no frozen clods of earth were placed in the embankment. The main feature of the work was the digging of a trench where the dike was to be reinforced on the outside about 0.80 meter (2.62 feet) to 1.80 meters (5.90 feet) wide at the base with a slope of 1 on 5. These trenches were carried down to compact earth, and there were two special objects in view, one to cut off any water channels leading through the old embankment, and to cut roots of old trees that had been left in the old embankment. These trenches were filled up with good material, well rammed. The plan of the work is shown in figure 1 (No. 38). It was often the case that the new and larger dike must be built almost entirely outside of the old dike and often also there were found in the old dike stumps with roots which must be removed in order to stop filtrations under the new work. The general plan was to dig trenches like those above described and carry out the work generally as is shown on cross section, figure 2 (No. 38).

Examinations made after the works were executed showed that the material was very compact and dry. The method of mixing chalk, either in the shape of milk of chalk or by sowing it over the material as the work progresses, was very common and gave excellent results,

the material often becoming hard and resembling béton. Another advantage of the chalk in the dikes is the destruction of worms and other larvæ with which the earth was filled. When these worms are killed the moles do not any longer infest the work, because their food is no longer there. The chalk also has a tendency to encourage the formation of soil suitable for grass and other vegetation. In dikes built entirely *de nouveau* a trench is usually built in the work and filled with puddled clay, carried down some distance below the bottom of the canal. Sketch, figure 3 (No. 38) shows the cross section of such work.

b. Consolidation and protection of slopes.

This has been done by sodding or by stone packed on the slope.

c. Building masonry under the trunk and the dike.

Great care had to be taken to prevent the leakage of water at such construction. The principal measure taken was to prevent the walls from coming in contact with the earthwork of the embankment. The extrados of aqueducts and siphons laid under the work are always placed about one-third of a meter (1.09 feet) under the bottom of the canal and covered with a bed of béton or of clay, strongly rammed. This is also necessary to prevent the roof of these works from being injured by the boat hooks of the boatmen. It is very important to leave such masonry uncovered until it becomes well set and very hard.

II. Description of the work for transforming the smaller canals into the larger canals and executing works of impermeability along the first levels of the canal. As an illustration of the method employed a sketch is given in figure 4 (No. 38). The roots of old trees appear to be the principal obstacle in the way of good work.

III. Works to prevent leakage executed at the time of building the canal.

For the purpose of rendering the trunk of the canal dry in lands where the soil is very permeable there was built a hydraulic bed of béton 0.15 meter (0.49 foot) thick covered with a thin coating of cement. This béton bed is placed about a quarter of a meter under the bottom of the canal trunk and is covered with clay strongly rammed, so as to protect the béton against the boat hooks of the boatmen.

IV. Résumé and conclusions.

The author briefly sums up the points which have already been stated in the paper.

PAPER BY MR. MELOTTE, ENGINEER OF PONTS ET CHAUSSÉES OF BELGIUM.

The writer confines himself to a description of the works on the canal from Maestricht to Bois-Le-Duc. This canal is fed by water from the Meuse at Malestricht. It is a canal both of navigation and

irrigation, and also serves as a feeder for other canals below Maestricht as well as for the irrigation of the District Campine and the Pays-Bas. The whole network of these navigable waterways comprises in round numbers about 400 kilometers (248.5 miles), of which 250 kilometers (155.3 miles) are in Belgium and 150 kilometers (93.2 miles) in Holland, and the area irrigated is about 2,200 hectares (5,434 acres), nearly all of which is in Belgium. This is, however, insignificant compared with the lands benefited by this irrigation in the Provinces of Antwerp and Limbourg. The benefits from irrigation would be much larger even than above stated if there were plenty of water. Unfortunately the quantity of water for this purpose is limited. During dry seasons there is hardly enough for the navigation itself, so that the State has been obliged to refuse, in the interest of navigation, any concession for taking the water for irrigation purposes, and even the navigation itself will soon lack the necessary water if the canals are deepened, as it is expected they will be, to accommodate traffic. It is therefore seen that it is necessary to adopt every possible means to prevent loss of water from the canal.

The writer goes on to describe the means employed, particularly upon the Belgium canal from Maestricht to Bois-Le-Duc, about 42 kilometers (26.10 miles) long, of which the first 9 kilometers (5.58 miles) are in excavation and the remaining in embankment. The first part receives a good deal of water by infiltration from the Meuse, which is near by, separated only by a narrow strip of land, and also from adjoining lands and two or three small streams. These sources of supply are quite considerable during the season of floods, but in dry seasons are very insignificant. The second part of the canal, and the longer part, being in embankment and traversing sandy lands and through marshes, is reenforced with dikes and counter dikes built almost entirely with sand, and in spite of the thickness and the good maintenance of these works there is a good deal of filtration. At the beginning of this stretch of canal the leakages have from the beginning been met, partly at least, by deposits from the muddy water from the Meuse. But there is one drawback to this method, and that is, these deposits finally obstruct navigation, and they have occasioned an expense of about 25,000 francs ($4,825) for their removal. Outside of this natural means the State has executed various works which have had a good result in the way of making the canal tight, although the principal purpose was to protect the banks against erosion. Although irrigation has been one of the principal features of this canal, yet it is essentially a navigation route of the first order. Its tonnage has increased from 530,856 tons in 1886 to 1,116,118 tons in 1897. The use of steamers has greatly increased in recent years both in draft and in speed. Many of them have a draft of 1.90 meters (6.23 feet) and a speed of 10.8 kilometers (6¾ miles) per hour, and it has reached at times 15 kilometers (9¼ miles) per hour.

In 1897 the total number of steamers and towboats which passed the frontier line was 1,747, about 20 per cent of the total number of boats. Until recently the protection of the banks has been accomplished by planting willows and reeds, but as the navigation developed this had to be given up and more effective systems introduced. Since 1888 the slopes have been protected by stonework laid in masonry, shown on fig. 1, Plan I (No. 39). It is about a third of a meter thick, laid on a bed of sifted gravel about a quarter of a meter thick. The stones are not cut, but are in the rough, well laid, and the joints filled in with mortar of very hydraulic lime. The rock rests on the natural soil, with a seat arranged of rough stone laid dry, and the berme of this rock is, where it rests on the earth, protected by a mass of gravel. These revetments have given good results; they not only protect the banks, but at the same time assure its impermeability. This revetment extends about three-quarters of a meter above the ordinary level of the water, and above that is a protection of turfing. The cost per square meter is about 5¼ francs ($0.85 per square yard), comprising all the work. This would be per running kilometer (0.62 mile) about 18,218 francs ($3,516.074) for each bank; the cost of maintenance is about 150 francs ($28.95) per kilometer ($17.97 per mile) for both banks.

As will be seen, the cost of these works is not very great, but unfortunately their execution requires the lowering of the water at least 1.60 meters (5.25 feet), and of course the interruption to navigation. The navigation interests have protested against this very strongly, and the department of public works directed the author to study a system of protection of the bank which could be put into execution without delays to navigation. He proposed two types, differing from each other only in the character of materials employed. The first is a construction in wood and the second in béton of cement. He considers that either method is certain to protect the banks and prevent leakages. As the work has never been carried out, it is sufficient to refer to the Plans Nos. I and II (Nos. 39 and 40), and to give only a few main features in this description. As the plans show, referring to Nos. 2 and 3, Plan I, there is a line of piles and a close line of sheet piling which is dove-tailed, making a tight protection, and the tops of both piles and sheet piles held in place by a waling streak, the top of the woodwork resting at the low-water level. The masonry and gravel and turf protection behind are very similar to that already described and in use on the canal.

The second plan, which is practically the same thing in béton, has, in addition, a transverse beam of béton running back into the bank and connected with the work in front by an anchorage; also a square béton pile about 2½ meters (8.20 feet) long, driven into the solid ground. In the case of the béton sheet piles, they are placed perpendicularly.

A very heavy system of this kind is shown on Plan II (No. 40), and, as will be seen, the béton parts are strengthened by round or square iron rods running entirely through them. The cost of the first method in wood and with the timber in its natural state, not creosoted, is 24 francs ($4.63) per running meter ($1.41 per foot). The less expensive béton method is estimated at 45 francs ($8.68) per running meter ($2.65 per foot).

PAPER BY MR. L. BARBET, CHIEF ENGINEER, PONTS ET CHAUSSÉES OF EPINAL, FRANCE.

NOTE BY THE EDITOR.—This paper is very lengthy, comprising 33 printed pages. It covers a great variety of subjects and gives details of many works. Only the main features of it can be given in the résumé.

I. INTRODUCTION.

The Paris Congress, after discussion of a paper by Messrs. Bompiani and Luiggi, of Italy, adopted the following conclusions:

The section is of the opinion that the study of the various systems of tightening the trunk of canals connected with that of supply appeals permanently to the attention of engineers and of navigation congresses. It considers that it ought to recommend specially, from the point of view of economies to be realized, that of the thickness to be given to the béton and of the special features of that kind of work.

The author then goes into the developments in line with the above recommendation.

II. VARIOUS SYSTEMS OF MAKING CANALS IMPERMEABLE.

The methods to be employed depend essentially upon the nature of the land traversed by the canal, the level of the water surface in relation to the waters outside, and finally upon the extent and importance of filtrations. The three principal systems are:

(*a*) Deposit of material upon the bed and slopes of the canal.
(*b*) Puddle walls (corrois).
(*c*) Béton.

III. DEPOSITS.

When canal levels slightly permeable are left to themselves, especially in those sections of a canal near the point where the feed waters are let in, and which are more or less muddy, the trunk of the canal is covered little by little with mud, which enters the interstices of the soil and stops them up partly. This method is very old, very simple, and well-known to engineers, and it does not incur any expense. It is successful when the general filtrations are of little importance, when the feed waters are relatively abundant, and especially in times of flood,

when the waters are charged with a large amount of sediment. This method is sometimes employed artificially by throwing clay upon the surface of the water and allowing it to settle to the bottom. Sometimes by placing small piles of the clay on the slopes, a little above the level of the water, so that it will run down the slopes into the bottom. Also sand is used with grains of some size, with wood shavings, with coal cinders, etc. The results of these methods are very variable, depending upon the nature of the surrounding lands and the material in the trunk of the canal and upon the channels to be stopped. On the Marne Canal sand or clay has been used where the loss of water does not exceed 2 cubic meters (70.64 cubic feet) per running meter of canal in twenty-four hours. Even where the filtrations are considerable this method will sometimes reduce the loss by one-half. On the canal above mentioned the losses at one place, where the canal is in large part cut in gravel, were equal to 15 cubic meters (529.80 cubic feet), but it was reduced to 4 or 5 cubic meters (141.28–176.60 cubic feet) after the use of green sand. Several other examples are given of the same method. The cost of such work depends upon the local conditions and the character of material. In the use of sand it runs from 4.50 francs to 12 francs ($0.27 to $0.71 per foot) per linear meter of canal and 3 to 4 francs ($0.18 to $0.20 per foot) by the use of oak shavings.

IV. PUDDLE WALLS (CORROIS).

When the losses of water are too great for the first method above described recourse is had to a method more costly but more certain of success, namely, puddle walls of clay or sandy clay. When the corrois are employed to stop general filtrations they cover the whole trunk of the canal, and are designated in this paper by the name "general corrois." When they are used to stop infiltrations more or less local through the dikes the name "lateral corrois" is given to them.

Preventive works.—Corrois are recommended for sections in embankment and in building the canal, and where the character of the dikes would make the canal safe or unsafe it is taken for granted that the ordinary methods of preparing the soil on which the dikes are to rest are carefully followed. On several canals a corrois 2 meters (6.56 feet) wide and sunk 0.60 meters (1.97 feet) into the natural soil is constructed. (See Pl. I, fig. 1, (No. 41).) The material is clayey and very carefully broken up and put on in layers of about 0.10 meter (0.33 feet) thick, sprinkled and then rammed until the layers are reduced to two-thirds of their original thickness. The price per cubic meter varies from 0.30 to 0.40 franc ($0.04 to $0.059 per cubic yard). In an important canal around Douai, through marshy and peaty lands, it would have been unwise to place embankments upon them without special consolidation work, which consisted in drying the marsh by pumping, removing the turfy covering over the whole width of the

trunk and of the foundation of the dikes, and by placing the bottom of the canal and the base of the dikes in good clayey material, heavily rammed, and to build corrois about 4 meters (13.12 feet) thick, sunken 0.50 meter (1.64 feet) into the gravelly sand. (See Pl. I, fig. 2, (No. 41).) After three years' use of the canal no infiltration was found. The work cost about one-half franc a cubic meter. In another canal, where one dike had to be removed to widen the canal, work of this kind which had been done previously showed no leakage. In this case the plan was like that shown in figure 3, Plate I (No. 41). The work cost a little over a franc per cubic meter.

General corrois.—This work is illustrated by the revetments of this kind on the Marne Canal and constructed according to the plan shown on figure 4, Plate I (No. 41). It is simply a covering of earth, 3 parts of sand to 2 parts of clay, put on in layers about a tenth of a meter thick, sprinkled and rammed, so that these thicknesses are reduced to two-thirds of their original thickness. The entire coating has a thickness of 0.20 meter (0.66 foot) at the bottom of the canal, and 0.20 meter to 0.30 meter (0.98 foot), measured at right angles, to the slopes. It is covered with a mat work of ordinary earth about a third of a meter thick at the bottom of the canal and a half a meter on the slopes.

The author gives several illustrations somewhat similar to the above.

On Plate I, figure 5 (No. 41), is another section of methods employed, where the thickness is a little less than half a meter in the trunk of the canal and about nine-tenths at the base of the slope and three-tenths at the top. It is necessary in such cases to protect the corrois, by a covering in half corrois about two-tenths of a meter thick on the slopes and fifteen-hundredths of a meter on the bottom, against the boathooks of the boatmen. This system of corrois has been applied on many navigable waterways, notably on the Bourgogne and Central Canal, where it is preferred to béton when the embankments have to submit to any movement. This part of the subject is closed in the author's discussion by describing very effective works, not yet finished, on the Marne Canal at Saone. For an example of the work, see figure 6, Plate I (No. 41).

Lateral corrois.—This subject relates to filtrations localized and found in the dikes, particularly when they are in an embankment. They do not always traverse the dikes at right angles, but sometimes at a very considerable angle, and the course is very tortuous. In that case the work consists in opening a narrow gallery or excavation, following the course of the leak and then filling up the excavation by a longitudinal corroi. This kind of work can be done without stopping the navigation.

General résumé in regard to corrois.—General corrois are recommended as preferable to béton when the works are upon compressible or sinking land and for embankments newly made, because in such

cases where béton is used it becomes cracked and broken up by the settlement of the dikes, but the corrois easily take the new form of the embankment under settlement. The best material is a natural or artificial mixture of two parts of sand to one of clay, rammed to two-thirds of the original volume. The spreading of chalk in powdered form upon the beds on which the corrois are to be placed, is quite useful. Again, general corrois resist better than béton the effect of subpressures. The price of this kind of work is also less than that of béton. It is difficult to give a close figure for the cost of the work; it varies from 2 to 4½ francs per cubic meter ($0.30 to $0.70 per cubic yard); that is, about 35 to 80 francs per linear meter ($2 to $4.80 per foot) of the canal; say for an average, 65 francs ($4 per foot.) The labor upon it represents about a third of a franc per cubic meter and half a franc when it is done by roller. In reference to the price in the dikes themselves it depends upon the dimensions and the depths to which they are carried.

V. BÉTON.

The method giving the most immediate and complete results when the land is adapted for its application is a revetment of the entire trunk, both bottom and slope, with a masonry covering, ordinarily formed of béton made of mortar of hydraulic lime. It is especially useful when there is fissured rock in the bottom or gravel where the pebbles are more or less mixed with sand, and generally where the base of the work is too permeable for sedimentary deposits described in the first chapter. The importance of this subject, as relates to béton, requires a division of it into paragraphs. The author then treats of the subject under the following heads:

The thickness to give to the béton covering.

Thickness of the mortar covering over the béton.

The revetment of the béton with earth and the necessary protections at the line of the water surface.

The means of stopping the subpressures.

The types employed shown in cross sections. The method of execution and the price of béton work.

Thickness to give to the béton covering (*chemise*).—The thicknesses of bétons vary very much between one waterway and another, sometimes differing greatly on the same canal according to the time they were laid or the nature of the land to be made impermeable. On the canals in the north of Italy the oldest have a thickness of 0.20 meter to 0.30 meter (0.66 to 1 foot), reduced to 0.13 meter (0.43 foot), and even to 0.10 meter (0.33 foot) on most recent works. In France at certain locations there has been given much greater thickness, reaching 0.35 meter (1.15 feet), but such a thickness is quite uncommon and the general tendency is to make them quite thin, consistent with good exe-

cution of the work. The greater thickness has been required often for the purpose of making the béton strong enough to resist a settlement of the foundations. The current dimensions, not comprising the coating, vary from 0.10 meter (0.33 foot) to 0.15 meter (0.5 foot). The author then gives the exact dimensions, and in detail, of the thickness on several important canals like the Eastern Canal and those of the upper Marne. He then states that from the study of the subject it is safe to give general dimensions, although not precise in every respect, as the variable conditions must always be taken into account. They are as follows:

Thickness at the bottom of the canal 0.15 meter (0.5 foot), when there is no subpressure, and 0.20 meter (0.66 foot) when there is subpressure. The thickness upon the slopes to average the same. These dimensions do not comprise the coating, if such there be, over the béton.

Coating over the béton (chape).—A coating, generally about 0.02 meter (0.065 foot) thick, is often used, sometimes made of cement mortar, but most often of hydraulic lime. Often, however, this covering is done away with and the work is limited to strongly plastering the surface of the béton and heavily ramming it. The author also describes quite fully the process and the advantage of coal tarring, and he gives the result of some experiments to show the great advantage of the latter method. These experiments consisted of forming the béton, according to different methods, at a certain point in the bottom of the canal, ramming and smoothing, sprinkling with pure liquid cement, and with a bed of coal tar, and without these different applications. The tests were made by forming a dam around the parts treated and filling it with water, and then setting a bucket filled with water near it and then watching the extent of the leakage and evaporation. It was found that with coal tar there was no leakage whatever, and where the sprinkling of the béton with pure liquid cement was made there was then very little leakage. From other extended experiments it is seen that a simple covering of mineral tar without cement covering (chape) reduced the losses more than nine-tenths. The author, upon these results, gives the opinion that with the use of thick or fat mortars one can, without any serious inconvenience, do away with the chape. He expresses a very strong opinion upon the remarkable effect of coal tarrage. After some little time the tar penetrates a considerable distance into the chape, whether it is in béton mortar or not, and in this way it closes up any fissures which have formed during the setting of the mortar and in this way forms a complete tightness at a minimum expense. Finally, he states that if the water for feeding the canal is very restricted in amount, and it is necessary in consequence to stop every leak, in that case pure liquid cement, with coal tar or a covering of coal tar, will be very useful.

Earth revetment; protection of the bank at surface of the water.—Béton coverings intended to insure the permeability of the trunk of canals are likely to be injured by ice and by the boat hooks of the boatmen. To protect against these injuries a revetment formed of mats of earth are often used upon the slopes and even upon the bottom placed over the béton. In the north of France the bétons are not revetted. In this region the boatmen use their boat hooks above the level of the water. In the eastern part of France, particularly on the Marne, an earth revetment is always used. The traffic there is heavy, curves numerous, and wind often violent, so that the boatman is obliged to use his boat hook. There is also a second cause for deterioration, and that is the rigorous climate. On the Central Canal it has been noticed that the béton has been injured by the ice and the rubbing of the boats.

Speaking generally, the earth revetment is about 0.30 meter (0.98 foot) at the bottom when it is revetted and from 0.30 meter to 0.70 meter (0.98 to 2.30 feet) on the slopes. As has been said, the greatest exposure to injury is at the surface of the water, and various methods have been adopted for increasing the thickness of the revetment at that level. The first consists in forming at a point about half a meter under the water a berme about half a meter wide, as is shown on Type No. IV, Plan II (No. 42). Various other methods of protecting this part of the slope by small masonry walls and by masonry slope walls are shown in Types VI and VIII and also on Types V and VII, Plan II (No. 42). The details of these methods are fully given in the text.

Subpressures.—A detailed description of the methods refers directly to and is fully illustrated by the cross sections shown on Figure IV, Plan II (No. 42). It can be seen from these that it is simply a method of subdrainage, either by pipes or small masonry drains; generally about two-tenths of a meter square, and generally three of these longitudinally, two at the bottom of the slopes and one in the center of the canal, with cross drains connecting with them spaced about 200 meters (656 feet) apart. The waters collected by this subdrainage are either discharged at certain points through the dikes and into lower levels outside or by means of automatic valves are discharged into the canal itself, when the level of the water in the canal is lowered to such an extent for any reason that the pressure from above upon these valves is less than the upward pressure from the subterranean waters. When the level of the canal is again restored, the additional pressure of the upper waters shuts these valves. The author then gives the dimensions of his various types of cross sections shown on No. 42, and gives the details of the various thicknesses and dimensions of drains, most of which appear on the plates themselves.

The proportions and mixing of béton.—From experience on the Eastern Canal, and the Marne Canal also, the following mixture has

been found satisfactory: Strong (gras) béton: Four parts of gravel or broken stone and 3 parts of mortar. Ordinary béton: Four parts of gravel or broken stone and 2 parts of mortar. As to the *mortar itself*, it is generally formed, on the Marne Canal, of 350 kilograms (771.75 pounds) of lime of Teil to 1 cubic meter of Moselle sand and the béton of 2 parts of mortar and 3 of gravel. The heavy béton is used where there is greater pressure. The author considers that gravel is always preferable to broken stone, and that in the former case the mortar should be mixed separately and the pebbles added, even when the gravel contains the proper proportions of sand and pebbles. The question of mixing by hand or by mechanical mixer is discussed, the author favoring the former method. He then describes the detail method of placing the béton on the bottom and on the slopes and the ramming of it all very carefully in order to get a compact mass and to place all of the pebbles below the surface, the final ramming being done by a light ram like a shoe with nails driven into it and the heads protruding. These should not weigh more than from 4 to 10 kilograms (8.82 to 22.05 pounds). After this part of the work is done the whole is examined very carefully and a trowel used to smooth over all voids or uneven places. If a chape is used there should be about twenty-four hours' interval before cleaning off and sprinkling the béton or putting on this last covering. It is important in putting on the different successive beds of béton to leave no sharp edges when the work is stopped for the night or other reasons, but to leave an interrupted work with a beveled edge.

Coaltarage.—The author gives the precise directions in reference to the use of coal tar, how to heat it and how to spread it over the béton. There should be applied two or three coverings of the tar according to the degree of impermeability which it is necessary to obtain.

Revetment in earth; protection of banks.—In order to prevent slips it is best that the revetment should be in half puddle (mi-corroi); that is, by means of sandy clay well rammed.

Price of béton.—The author gives a detail table showing the cost of doing work according to cross sections No. V, VI, and VIII (No. 42). This table is of importance and will be valuable in designing and estimating similar work.

Revetments in masonry.—Before giving his conclusions the author alludes briefly to special cases and conditions where it is necessary or advisable to use a masonry rather than a béton revetment, especially in cases where there is a large number of wide fissures or openings in the bottom of an excavation which has been made in certain kinds of rock. He speaks of certain parts of the Eastern Canal, northern branch, cut in fissured rock, where impermeability has been obtained by using a masonry revetment and by utilizing the stone found in the excavation. On the canal Saint-Quentin, where the soil was very chalky and

showed enormous leaks, they were stopped by placing under the clayey puddle covering a revetment of bricks laid flat on a bed of mortar. He refers to the report of the fifth congress, presented by Messrs. Bompiana and Luiggi, describing in detail the revetments by paving on the canals of upper Italy.

VII. CONCLUSIONS.

The author gives from the lengthy paper sixteen conclusions, under the principal headings:

A. By deposits (colmatages).

B. Puddle walls (corrois).

C. Béton.

The choice between these three principal methods depends essentially upon local conditions—the form of the dikes, the nature of the land traversed, the level of the water in the canal compared to that of subterranean waters or of floods, and depending also upon the necessity of impermeability, either complete or partial.

(A) *Colmatages.*—1. Although recommended for their moderate cost (3 to 12 francs per running meter of canal) ($0.18 to $0.71 per foot), they do not give good results except in land which is only slightly permeable. The employment of granular sand, coal cinder, or such materials sometimes is sufficient for tightening a local opening where it can be clearly defined.

(B) *Corrois.*—2. These constitute a preventive method of impermeability, and are the most useful for dikes in embankment.

3. They are generally more economical than béton, and are generally preferable on works where the land is compressible.

4. They are generally durable only when they have a thickness equal to 0.80 meter (2.62 feet) at least. The interposition of a dry bed like a stone pavement (macadam) between the corroi and the land underneath produces the best effect upon embankments made of stone, and is recommended to engineers.

5. Good material for corroi consists of a mixture of two parts of sand to one of clay, rammed so as to compress to two-thirds of its volume. Spreading over the corroi a powdered lime is only useful for absorbing the excess of humidity found upon the beds to be puddled. A rolled corroi is preferable to one made by hand, both on account of economy and good execution of the work. Corroi generally resists subpressures a little better than béton, but if subpressures are to be feared it is best to stop their effects by the same means as those employed for béton revetment.

7. Corrois are especially useful in stopping local leaks, particularly in the form of practical keys in the center of dikes, deeply rooted in the soil below the dikes.

8. The price varies ordinarily from 60 to 70 francs ($12 to $14) per

linear meter of canal. It costs from 30 to 40 centimes (6 to 8 cents) per cubic meter when made by roller, and from 50 to 60 centimes (10 to 12 cents) when made by hand.

(C) *Béton.*—9. Of all the systems of making canals impermeable, béton is that which gives the most complete results, but it is scarcely applicable to compressible soils. It is particularly useful in cuts opened in fissure rocks or in gravel more or less mixed with bowlders or large gravel.

10. The thicknesses to be recommended with good mortar and béton well made, including the chape, if it be used, are as follows: At the bottom, where there is no subpressure, 0.15 meter (0.50 foot); in case of subpressure, 0.20 meter (0.66 foot); on the slopes, 0.15 meter (0.50 foot) at the base of the slopes, 0.10 to 0.12 meter (0.33 to 0.39 foot) at top; in case of subpressure, 0.20 meter (0.66 foot) at the base, 0.10 to 0.12 meter (0.33 to 0.39 foot) at the top.

11. Only first-class mortars should be used, made with the greatest care. The béton should be well mixed, and care taken to see that there is no preliminary setting of the cement before the béton is placed in the work.

12. The chape can be dispensed with often when the béton is smoothed over with a thick layer of cement and heavily rammed and smoothed, as stated previously.

13. The covering of mineral coal tar, heated, on béton revetments furnishes impermeability better than a covering in cement mortar.

14. The revetment on the bottom can be dispensed with by deepening the trunk (cunette) at least 0.30 meter (0.98 foot), but the revetment of the slope is always useful and often indispensable, for reasons already stated.

15. In levels submitted periodically to subpressures, it is quite necessary to stop their effect by subdraining, as already described and shown on the plan.

16. For a canal 10 meters (32.80 feet) wide at the bottom and 2.20 meters (7.22 feet) deep the average cost of béton per linear meter (not comprising the protection of banks) is about as follows:

Where there is no subpressure, 95 francs per meter ($5.60 per foot).

In case of subpressure, 115 francs per meter ($7 per foot).

PAPER BY MR. MATHIES, OF DORTMUND, GERMANY.

One of the most difficult questions in engineering is that of deciding how to construct works to insure the absolute impermeability of canals, in order to prevent the loss of water by infiltration, to diminish the expense of feeding, and to prevent injury to adjoining lands. If measures to accomplish these purposes are not taken when the work

is first undertaken it will have to be done afterwards at much additional expense, and, in addition to the dangers resulting to adjoining lands by a break in the dikes, there will always be large expenses on account of damages incurred.

The author does not undertake to go into a technical discussion or to review or criticise various means of accomplishing the purpose, but confines himself to a description of a work of which he had charge, namely, the section of the Dortmund and Ems Canal on the level of Herne-Munster, 67 kilometers (41.63 miles) long. He considers this work characteristic, particularly in respect to the use of bad materials. The plate (No. 43) shows a profile which justifies his opinion in reference to the difficult character of the work. The section crosses the valleys of two small rivers, the Lippe and the Stever, with a ridge between from which the material had to be taken for the embankment. The section extends from kilometer 23 to 31. Some of the embankment is 14 meters (45.92 feet) above the river land of the commune of Olfen, and the level of the water in the canal is in places 12 meters (39.37 feet) above the natural soil. The maximum cutting is 13 meters (42.64 feet); the width of the canal at water surface is over 30 meters (98.43 feet); the depth is nearly 4 meters (13.12 feet) in the portions in embankment and nearly 3 meters (9.84 feet) in those portions in excavation. The width at bottom is from 18 to 20 meters (59.04 to 65.62 feet); the soil to be excavated was composed of marl, above which was a bed of clayey earth about a meter thick; and, in the valley, marl with alluvial sand above it. The marl was very stony and very firm, so that in the cuts the slopes would stand nearly vertical. Of course, such material was not good for forming high embankments, but there was none other at hand.

The problem was how to judiciously use three kinds of material in this embankment. Experience and numerous observations show that when the marl is prevented from crumbling and falling to pieces and melting under action of water it preserves its natural cohesion and shows no alteration even after several years. However, rocky marl is full of voids and ought to be revetted, consequently, by covering it with a bed of better material. To commence the embankment he first carefully removed all the vegetable matter from the base and removed the layer of vegetable soil, so as to give a good connection between the subsoil and the materials from excavation. He also made careful examinations to ascertain if there were any subterranean water courses which would cause trouble, and finding some they were diverted.

Embankment was made in layers of the thickness that would naturally result from using small dump carts, and it generally varied from 50 to 60 centimeters (1.6 to 2 feet). He considers that the method by scrapers is very good, for the reason that the material is put on in very thin layers. He also in some parts of the embankment, in place of

ordinary breaking up and ramming the material, had a large number of horses, up to sixty, walk over the ground, and he states that there have been employed successfully in other places flocks of sheep for the same purpose.

After describing the building of embankments the author takes up the question of protecting the embankments from infiltrations from the water of the canal, adopting various methods of puddle walls, either vertical or sloping, and also a protection of the slopes on the outside, all according to the kind of material that is found at special places in the embankment. See plate (No. 43) for illustration of four methods employed. Note figure 4, which shows a vertical wall connected by a horizontal layer of clay with the opposite embankment by a bed of clay extending entirely across under the trunk of the canal. He objects to it, for the reason that the part on the right of this wall (see figure) is entirely disconnected with the part on the left, and consequently when A becomes saturated it brings a pressure to bear upon the outside, B, which is dangerous.

Various methods of ramming the puddle (corrois) have been fully stated by authors of special papers and need not be repeated. The methods which the author describes, illustrated by the plate, are, he states, satisfactory, and although the water was let into the canal more than a year ago it is still impermeable. He is of opinion that the methods employed could be used to advantage under similar conditions for large navigation canals. He calls special attention to the necessity of connecting the puddle at the base of the embankments and just under the bottom of the canal securely with the cuts on either end, extending these beds of impermeable material some distance into the excavations.

Fourth question.—Mechanically raising from level to level of the water supplying a canal. Means of transmitting direct or at a distance the power required for raising the water from level to level. Steam engine, electricity, water under pressure, etc.

PAPER BY M. GALLIOT-DIJON.

While the feeding of a canal is ordinarily done by introducing the water from neighboring water courses or from reservoirs established specially for the purpose and allowing the water to descend from level to level, yet in certain cases it is necessary to proceed in a reverse direction and make the water mount from level to level by means of machinery, which takes the water from some important water course situated at a lower level than that of the canal. The author then speaks of two cases where this was done in a temporary manner. The first was at the Briare Canal, made in 1882. This is one of the branches

of the Central Canal of France. During the entire year it lacked water for its summit level, and it was necessary to bring it from the River Loire and carry it up through a chain of 13 locks. It was done by using a portable engine operating a centrifugal pump, which raised 200 liters (52.85 gallons) per second, or 17,000 cubic meters (600,380 cubic feet) per day. This being insufficient, another plant was added which furnished 300 liters (80 gallons) and 26,000 cubic meters (918,320 cubic feet); these pumps only worked seven months that year, and they raised nearly 5,500,000 cubic meters (194,260,000 cubic feet) through the 13 locks. The total cost was 500,000 francs ($96,500), or per meter cube, 9 centimes (1.8 cents per cubic meter, or one-half mill per cubic foot). The second case was at the summit level of the Central Canal in 1882, where, by means of centrifugal pumps operated by portable engines, water was raised to the summit level or into a reservoir near this level. This water was taken from the Plessis Reservoir, which is 11.6 kilometers (7.19 miles) from the summit level. The total rise was 20.58 meters (67.50 feet). It is overcome by 9 locks. The work was done very much like that above described for the other canal. The cost per cubic foot is a little less than one-half mill. Although these works were hastily installed, they did very satisfactory work.

The author now describes at considerable length (12 printed pages) the permanent installation of the Bourgogne Canal. Only the salient points can be given in this résumé, but to those who are especially interested and can read the French the paper is recommended for careful study. The canal has a total length of 242 kilometers (150.04 miles). It is fed by two unimportant water courses and by six reservoirs, containing altogether, at the maximum capacity, a total cube of water of 28,000,000 cubic meters (988,960,000 cubic feet). The canal is quite leaky, particularly on the watershed of the Saone, for there the water course, the river l'Ouche, is quite insignificant, and the section of 30 kilometers (18.60 miles) which extends from the Saone to Dijon is very permeable, being in a plain of coarse gravel. Although every means was taken to make the canal tight, yet it was finally decided to make this section a part by itself and supply it from level to level by a pumping installation which is described in the paper.

There were three levels to be supplied by mechanical means, 6.9 kilometers (4.28 miles) in total length. It was necessary to give daily 15,000 cubic meters (529,800 cubic feet) to the three locks, and to take the water from the Saone and raise it to the first level, No. 76, in which level there was the largest number of lockages and of waste, and then to take 6,000 cubic meters (211,920 cubic feet) of this water into the next level above No. 75, and then to send forward to the summit level 3,000 cubic meters (105,950 cubic feet). The fall at each lock was 2.60 meters (8.54 feet) at No. 74 and No. 75 and 3.70

meters (12.14 feet) at No. 76. The weight of water therefore to be raised per second was 642 kilograms (1,415.40 pounds) at the lower lock, 181 kilograms (399.03 pounds) at the middle one, and 90.5 kilograms (199.51 pounds) at the upper one.

Method of installation.—About 2 kilometers (1.24 miles) from the embouchure of the canal at the river there is a barrage on the Saone, the fall of which would furnish the necessary motive power. This fall is 1.40 meters (4.59 feet). At low water in the Saone there could be furnished for the installation 21,000 kilograms (46,247 pounds). As less than 1,000 was required, there was evidently sufficient power. The author shows that electricity was the only force that could be used to advantage.

Calculations for the installation.—Each lock is provided with a dynamo actuating a centrifugal pump which takes the water from the level below and discharges it into the level above. Allowing an efficiency of 60 per cent for these pumps, the amount to furnish per second by these dynamos would be for the three locks above described respectively as follows: 151 kilograms (33,289 pounds), 302 kilograms (665.81 pounds), 1,070 kilograms (2,358.92 pounds).

The dynamos make the same number of revolutions as the pumps, and are coupled to the same shafts. The efficiency of the dynamos is figured at 74, 77, and 81 per cent at the three locks, respectively. Therefore, the kilograms to be furnished are as follows: At the lower lock 1,320 (2,910.61 pounds); at the middle lock 393 (866.43 pounds); at the upper lock 204 (449.82 pounds); or, in watts, at the rate of 9.81 watts per kilogrammeter equals 71 foot pounds per second; the total electric force was, respectively, 13,000, 3,850, and 2,000 watts, or a total of 18,850 watts. This power is transmitted by a triphase current of 2,000 volts tension. The diameter of the wire is one-eighth of an inch. Between the generating station and the first receiver station, which absorbs one-half of the energy, the line loses scarcely 1 per cent by overheating. At the receiving stations at each lock the current is brought down to 110 volts by transforming. Allowing on the whole line and through the transformers a loss of about 5 per cent, the generating plant at the barrage would have to furnish a total of 19,800 watts or 2,020 kilograms (4,454.10 pounds) per second. This generating plant has an efficiency of at least 85 per cent, and it would therefore require 2,370 kilograms (5,225.85 pounds) per second, or 31 horsepower at 75 kilograms (165.37 pounds) per horsepower. On the other hand, the efficiency of the turbine is 80 per cent, and it must furnish, consequently, about 39 horsepower; therefore we find that with a fall of 1.40 meters (4.59 feet) the gross power to be furnished requires a discharge of—

$$\frac{39.4\times 75}{1.4}=2{,}110 \text{ liters (556.07 gallons) per second.}$$

The accompanying plans I and II (Nos. 45 and 46) give in great detail all the features of the installation, and it is unnecessary to go into the lengthy description which the author gives in the text, except to state some of the most important features. The turbine is of the type known as the Hercules. It can give on its shaft 42 horsepower. By the various gearings multiplied, as shown in the plan, by bevel gearing and by belts, the velocity of the turbine of 50 revolutions a minute is carried to 340, where it is coupled onto the generating dynamo. This latter is of the Ganz type of triphase current. The various apartments of the generating house, also the point of transforming from 2,000 to 110 volts along the locks of the different levels, are all inclosed, so that there is no danger, and the poles which carry the wires of high voltage are protected by pointed wires, so that they can not be climbed, and at various points prominent notices are put up as danger warning.

Results obtained.—The installation was made in 1897. The works at the river were quite difficult, and it was not until January, 1898, that the installation could be put into use; and at the time of writing the paper the actual operations had not been carried out, but from preliminary working of the installation it is without doubt in every way a success. The cost is 80,000 francs ($15,440). It is more than sufficient to give 15,000 cubic meters (529,800 cubic feet) of water, and assuming that it will work 100 days in the year it will furnish a total volume of 1,500,000 cubic meters (52,980,000 cubic feet).

The author compares the result with the use of reservoirs, and allowing for the filtration from the reservoir to the canal, a distance of 90 kilometers (55.92 miles), the amount of water required by natural means would be 2,000,000 cubic meters (70,630,000 cubic feet), and such a reservoir would cost nearly 1,000,000 francs ($193,000), while the installation for lifting the water, as above described, was only 80,000 francs ($15,440). A comparison is made in great detail in order to show the exact relations, as near as can be ascertained, between a reservoir and the above-described mechanical plant.

Taking everything into consideration, construction, interest, maintenance, and other necessary work upon the reservoir, the cost can not be placed at less than 3 to 4 centimes per cubic meter ($\frac{1}{100}$ to $\frac{2}{100}$ mills per cubic foot), while the cost by the installation above described, taking into account all expenses, including interest, is not over 1 centime per cubic meter ($\frac{8}{100}$ mill per cubic foot).

Résumé.—The author's purpose was only to indicate the general features of the plan of feeding a canal by mechanical means. No absolute conclusions can be given, but he attempts to state certain principles, according to the experience given in the paper in 1881 upon a provisional works, portable engines and pumps, which, although put up in great haste, were successful in feeding the canal at a price

comparable with that of a reservoir installation, and one may consider that by building a permanent installation under more advantageous conditions it would be possible to obtain still greater advantages, which he says he has shown to be possible by the definite installation adopted on the Saone at St. Jean de Losne, above described.

Finally, it can be stated that there is a much easier solution to-day than there was in 1881, or even in late years, on account of the rapid progress made by the inventors of petroleum and gas engines and the use of these motors, either isolated or for a group of locks. Of course the natural and general solution of feeding canals will always consist of reservoirs, but the feeding by mechanical means has also a chance for development, thanks to continual improvements being made in machinery, and particularly the ease and economy of transmitting energy to a considerable distance.

CHAPTER IV.

THIRD SECTION—TIDAL RIVERS AND SHIP CANALS.

First question.—Formulæ of the characteristics of a tidal river. A. Enumerate in detail data to be collected in order to characterize a river and to be able to compare its régime and conditions of navigability with those of another river. Explain the meaning and value of the terms used so as to secure bases of comparison applicable to various rivers. B. Furnish in reference to one or more rivers the enumeration of the particulars above referred to.

PAPER BY MR. HENRI VANDERVIN, ENGINEER, PONTS ET CHAUSSÉES OF BRUSSELS.

NOTE BY THE EDITOR.—As this paper was taken as the basis of a lengthy detailed discussion of the first subject of this question, and as the decision of the section submitted to and approved by the congress was evolved from this paper, it must receive a comparatively full résumé.

General conditions.—The question submitted to the deliberations of the congress is not one of theory. It is not intended to explain phenomena or search after laws; on the contrary, it is intended to submit to the approval of facts the explanations given up to the present time of the phenomena of the maritime regimen of rivers, and to ask of experience the lessons which it can furnish us for the confirmation, the definition, and the development, and perhaps the correction of laws as at present understood and for the discovery of new principles. The method applied to the study of the hydraulic questions relating to maritime rivers has been very difficult up to the present time, not only on account of the complications of the phenomena, but also on account of the relatively small number of facts noted with precision, and differences in the method followed by those who observed them. This situation has attracted the attention of engineers who are engaged in such studies and especially those who formulated at The Hague Congress the principal question to be brought before the present congress.

The purpose of the congress ought to be to define in a general way the principal effect which different data relative to a maritime river

can have upon its regimen. We will, without doubt, all be in accord upon the principal data which it is desired to put into a formula, but the work to be done is to arrange these facts in a rational order and then to indicate how they can be registered in such a manner as to render most easy and rapid and sure the comparison of one river with another.

We state therefore, at the outset, and with the above purpose in view, that the congress will have to decide upon the question of the units of measure. If engineers belonging to different nations furnish data in reference to rivers with which they are acquainted by employing the measures of their own country, the comparisons will evidently become difficult and will result in great loss of time. As a time measure the second, the sixtieth part of a minute, is so generally employed that although it does not permit of calculation as simple as those of the decimal system, yet it is necessary to use it on account of its multiples, the minute, the hour, and the day. In reference to measures of length, from which are derived the measures of surface and of volume, a considerable diversity still exists. However, it may be considered that two important units only are employed ordinarily; these are the meter and the English foot. Others would appear to be eliminated without question. The metric system justifies itself by such rational principles and is so easy in calculation that, other things being equal, the preference given to it is incontestably right. Again, its use is extending daily even among those countries which up to the present time have resisted its introduction. It is more or less familiar to engineers of all countries; the future seems to belong to it, and these especial considerations would appear to justify the congress in adopting it in establishing the rules proposed. However, the English unit continues to be very much used by a large number of engineers, and a double standard would, perhaps, be justified. By the side of the metric measure there should be given in all data the English measure. It might, however, be advisable before deciding this question to consult the members of the section who generally use that measure and ask them if the adoption of the metric measure alone, in the data to be brought together, would give them trouble sufficient to justify a double unit.

The second question is that of language. Three principal languages have been employed up to the present time in the publication of proceedings of the congresses of navigation—German, English, and French. No doubt the publication of the formulae should be limited to these languages. However, there is a universal language known to and employed by all engineers. It is that of graphical representation of facts. It is therefore best to use this as much as possible. Diagrams are not only recommended from this point of view, but

still more from the fact that they place a multiplication of data in the most compact form and bring to the eye the facts given and permit of the easiest possible comparison and also the most rapid of the characteristic elements of the regimen of rivers—that is, if they are made to the same scale. It will therefore, consequently, be important to specify the scales for the diagrams, which the section will decide useful to recommend.

GENERAL DIVISION OF THE FORMULÆ INTO THREE PARTS.

The above general and preferable considerations being established, it is proper to make for each river three principal divisions of the data.

1. Those relative to the sea into which the river is discharged.
2. Those relative to the upper part of the river where the tide does not exist.
3. Those relative to the maritime river itself.

NOTE.—The important points are italicised.

REGIMEN OF THE SEA.

In order to obtain full knowledge of the *sea or bay into which the river discharges itself*, there ought to be briefly given the regimen of the tides, indicating their propagation by *cotidal curves*, by noting the *maritime currents before and in the vicinity of the embouchure, the normal amplitude of the tide, its value in spring and neap tides, the depth of the water along the shore, the direction of the prevailing winds and tempests, and their influence on the height of the tide.* There ought to be known then the *nature of the bottom* in front of the embouchure *and that of the coasts and the importance and height of waves* in tempests which could have an effect upon the bed of the sea and raise the materials of which it is composed. If a bar exists in front of the embouchure, it ought to be defined by its height below normal low tide, its width, its length, and the nature of the materials of which it is composed and the changes which are observed. It will then be interesting also to know if, in a general way, the sea tends to gain or to lose in reference to the shore in the vicinity of the embouchure.

SECOND PART, REGIMEN OF THE UPPER RIVER.

The part of the river not subjected to tidal action exerts an influence only upon the maritime parts by the volume of the water which it brings to it, which we call natural waters, "eaux naturelles," in contradistinction to the water of the sea. It will be important at the outset to know the *normal discharge* of the river immediately above the maritime region. This information will be completed by indications upon the extreme condition of the waters—that is to say, upon the

period, the frequency, the duration, and the discharge of floods and the duration and mean discharge at low water. The height of the water in these different conditions will be registered and the bed defined by a plan, a longitudinal profile, and by cross section.

THIRD PART, REGIMEN OF THE FLUVIAL TIDES.

The *bed* in which the flood and ebb currents flow will be defined by means of a *plan*, by a *longitudinal profile* following the deepest channel (thalweg) cross-sections and diagrams of kilometric *curves* of the *sections and the width under low tide* and of *sections and mean widths at half tide.* The plan of the estuary will be completed by drawing contours at such a vertical distance apart as the scale of the plan will permit.

The *nature of the bed* will be noted, showing the differences which appear at different points, especially in the thalweg, particularly in point of view of permanency. The regimen of the normal tides will be characterized by a diagram of *simultaneous local curves* made from posts of observation installed on the banks of the river. *Instantaneous profiles* from hour to hour, starting from high tide, will then be deduced from this diagram. The same information will be given in respect to spring and neap tides with the normal discharge of the upper waters, also that of normal tides with floods. The *point where the tide ceases to be felt* in these various conditions will be indicated. There will also be registered the *point up to where the flood current ceases to be felt* under these conditions. There will then be given the *volumes delivered below or introduced above* in the same intervals of time into the successive sections taken at regular distances apart, starting from the embouchure, for example, every 5 kilometers. For each of these stations there will be deduced a *curve of discharge per second* and a curve of mean velocities.

The propagation of the flood can be shown by a diagram on which the distances are abscissas and the ordinates are *velocities per hour of the head of the flood and of the summit of the wave;* these velocities being deduced from the time that is required for the head of the flood or the summit of the wave to cover the distance separating the station below from that which corresponds to the distance shown by the ordinate under consideration.

The quantity of matters in suspension will be shown as far as the nature of the materials carried will permit. There will also be indicated the character and amount of materials composing the banks, distinguishing those brought from below from those coming from above. If the bed has been subjected to *changes under the action of natural forces, they are to be shown.* Also there are to be indicated the modifications which have been made *by man*, and the results of these modifications.

Formulary.—The order and the choice of the essential elements to be brought together being thus defined, the formulary can be deduced as follows:

NAME OF THE RIVER.

FIRST PART, REGIMEN OF THE SEA.

1. Chart to the scale of $\frac{1}{100000}$ of the region of the sea into which the river is discharged, and on which are drawn the cotidal curves.

2. Show the maritime currents above and in the vicinity of the embouchure.

3. Range of the tide in normal weather—both spring and neap tides.

4. Depth at normal low tide at the opening of the embouchure.

5. Direction of the ruling winds and of tempests; their influence on the height of the tides.

6. The character of the bottom above the embouchure and the nature of the neighboring coasts.

7. Height of waves in tempests.

8. The bar; its location; the depth upon it below a normal low tide; its width; its length; the nature of the materials which compose it; the variations that have been observed.

SECOND PART, REGIMEN OF THE UPPER WATERS (EAUX SUPÉRIEURES).

1. Normal discharge per second of the river waters.

2. Period, frequency, duration, and discharges of ordinary and extraordinary floods.

3. Period, duration, and discharge at low river.

4. Diagram classifying for one year the discharges according to the number of days during which they were observed—the abscissas to show 365 days of the year; the ordinates to show the discharges. The discharges comprise successively from 10 to 20 cubic meters (13 to 26 cubic yards), and from 20 to 30 (26 to 39 cubic yards) outside. Scales: Abscissas, 0.001 meter (0.003 foot) per day; ordinates, 0.002 meter per 10 meters cube.

5. Level or surface of the water. See profile, described following:

THIRD PART, REGIMEN OF THE FLUVIAL TIDES.

1. Chart or general plan of the river, with a scale of $\frac{1}{20000}$, with curves of surface.

2. Longitudinal profile following the deepest channel (thalweg) from the sea to 1 kilometer above the limit of the tide; this profile to be projected upon a vertical cylinder, of which the axis of the course of the water is the directrix. Scales: 0.01 per kilometer; heights 0.01 meter per meter.

3. Cross sections at different points of inflection in the course or at the summits of the curves.

4. Diagram of the wet sections under normal low tide and between normal, low, and high sea. Scales: Abscissas, distances following the developed course of the river, 0.01 meter per kilometer; ordinates, wet sections, 0.001 meter per 1,000 square meters. The same for widths.

5. Diagram of the kilometric curves. Scales: Abscissas, the distances following the developed course of the river, 0.01 meter per kilometer; ordinates, kilometric curves. On this diagram there will be indicated as a second curve the corresponding depth of water below normal low tide in the principal channel.

6. Indication by zones of the nature of the bottom and banks. A horizontal column under the longitudinal profile will show the bottom materials found in the course of the thalweg.

7. Diagram of the simultaneous local curves for normal tides—that is to say, the tides being considered abscissas, the local curves will be represented by the intervals of time which separate the hours of high sea at the different stations where the curves have been registered. Scale: Abscissas 0.002 meter per 10 minutes; ordinates 0.05 meter per meter.

8. The longitudinal profile defined under No. 2 above will be completed by indicating the geometric loci of the high tides and of the low tides and by the instantaneous curves taken hour by hour from the high sea, both for normal tides and for the normal upper waters. The diagrams No. 7 and 8 will then be given for the normal tides, with the great floods of the upper waters and for the spring and neap tides successively, in connection with the normal upper waters and extraordinary floods. On each one of these various profiles there will be noted the two points where the sea ceases to raise the waters and where the flood current ceases to make itself felt.

9. The volumes introduced into or withdrawn from the successive sections, taken at distances of 5 kilometers one from the other hour by hour from the high sea, will be given in tabular form.

10. From the volumes of water passing per hour into the varying sections and exhibited by table under "9th," there will be deduced for each hour a mean discharge per second. A diagram of discharges will be made by joining by a continuous line the extremities of the ordinates representing these mean discharges in intervals of an hour, as sufficiently explained by the figures on the adjoining diagram (No. 47). The periods of the turn of the flood and ebb tide given by the intersection of the curve of discharges with the axis of the abscissas will be noted on the diagram.

11. On the same diagram there will be shown the mean velocities, being quotients of the mean discharges per second by the correspond ing wet sections. These mean velocities will serve for a tracing of a curve of mean velocities.

12. Diagram of the propagation of the flood.

Abscissas: Distances of stations, 0.005 meter per kilometer.

Ordinates: First curve: Distance separating the station considered from the station below.

Velocities: =time in seconds required for the head of the flood to cover this distance.

Second curve: Analogous to that which relates to the velocities of the summit of the wave.

13. Quantities of matter in suspension per meter cube of water.

14. Materials composing the banks: A, coming from below; B from above.

15. Indicate the variations observed in the bed of the river.

16. Indicate the modifications made upon the bed of the river artificially and the result of these modifications.

PAPER BY MR. L. FRANZIUS, OBERBAUDIREKTOR, OF BREMEN.

NOTE BY THE EDITOR.—The extended experience of Mr. Franzius on very successful river training works, particularly upon the River Weser, gives great value to his statements, and therefore the discussion of this subject by him will receive a comparatively full résumé, particularly because it uses as an illustration the improvements upon the Weser itself.

FIRST PART.—*Enumeration and discussion of information characteristic of a tidal river (rivière à marée).*

All rivers which empty into the sea, and they comprise the larger number of rivers, undergo at their embouchure a change of regimen which depends upon the nature of the sea. The greater the amplitude of the tide, the better known and the more marked is this change. This change is, however, also produced in the case of a sea without tide, due to waves and oscillations caused by winds and by tidal currents scarcely perceptible to the eye. These various causes united, can become so important that the river at its embouchure preserves very little comparison with the conditions above the embouchure. In arriving at a general understanding of the matter, there is made in this paper a distinction between embouchures without or with a feeble tide and embouchures with a tide of great amplitude, although it is impossible to trace closely the limit between these two classes. In the study of the question of how to class a river embouchure in one or the other of these divisions, the *relation between the discharge of the river above and the amplitude of the tide at the embouchure* would play an important part. *The embouchure*, or the *region* of the embouchure, comprises the part of the river of which the regimen *depends on the sea*,

and of which the lower limit, i. e., that part toward the sea, is found where the currents of the river are only scarcely perceptible. The limit above, i. e., that part toward the land, is where the river begins to take the characteristics of the maritime region. These limits can not be traced with precision, because the transition from one part to the other is gradual.

The embouchure will take the form of a *funnel* or will form a *delta*, which depends upon the relation between the power; that is to say, the discharge of the river as to water and solid matters and the amplitude of the tide of the sea into which the river empties.

The formation of deltas is preceded by that of *bars*. Under the name of *bars* is comprised the deposits which extend over the whole width of the river, or which form themselves in front of the embouchure and preserve a *fixed position*, simply because the cause which has produced this formation persists in a constant manner. This cause is really a diminution of the velocity of the river waters. A bar will always form when the water has lost its velocity either by a sudden enlargement of the section or by a sudden diminution of the slope of surface.

A. *Embouchures where the tide has a small amplitude.*—These embouchures are classed in two divisions, according to whether the river discharges directly into the sea or traverses a large bay communicating with the sea by a pass (goulet). According to the considerations upon embouchures developed above, a delta will always be produced in the first case, except where the river is not of great importance or the depths of the sea along the coast are very large, or where there are strong tidal currents. In the latter case the solid matters carried by the river will nearly all be absorbed by the sea or will be carried to a distance by it. In the second case the river has, so to speak, two embouchures which follow each other, the upper at the entrance of the bay at the pass, the second at the sea. There generally exists a great difference between these two mouths. In the case of an embouchure with a delta the slope of the surface will be nearly always directed from the interior toward the sea, and it is only occasionally under the action of the wind that the slope is from the sea toward the land.

B. *Embouchures where the tide is of great amplitude.—The maritime region of a tidal river* comprises the *region of the embouchure*, the estuary, and the *maritime region above*. According to what has been said above, the region of the embouchure comprises the part of a river which possesses all the characteristics of the sea, while the upper maritime region extends along that part of the river limited by fixed banks and subjected to the action of the flood and ebb tide. It is upon the form and the depth of the bed in the region of the embouchure that depends the movement of the tidal wave in the regular bed. It penetrates into the maritime region above without losing its force, and

preserves, generally, the same velocity of translation which it possessed in the open sea; while in another bed, and an irregular one, this tidal wave is held back by the obstacles which oppose its propagation. In any case, it will propagate itself until its force is exhausted, i. e., until the hydraulic axis of the river is no longer changed by the action of the tide. At this point is often the *limit of the maritime region of the river* or the *limit of the tide.* It is incontestable that during the same flood the force of a tidal wave diminishes continuously from the embouchure up to this limit, although, as will be shown further on in detail, the height of the tide can alternately increase or decrease between the different points of the maritime region. In general, the limit of the maritime region should not be confounded with the *limit of the flood current.*

The location of the limit of the maritime region, as also *the location of the limit of the flood current*, depends upon the height of each tide as much as upon the volume of the fresh waters; that is to say, upon *a discharge of the upper river.* These locations can be considerably varied in accordance with the discharges of the river. Not only is the upper water lifted by the tidal wave coming from below, as by a barrage, but it is completely turned back upstream to the point where the force of the wave is finally overcome by the force of the discharge of the river itself.

The velocity of currents should not be confounded with the *velocity of propagation* of the different parts of the tidal wave. The velocity of the currents depends on the section of the river and on the slope of the surface of the wave, and it can be considered as a function of the velocity of propagation of the tidal wave. As a general thing, the velocity of the progagation of the tidal wave is greater, considerably, than the velocity of the currents, and particularly as the tidal wave approaches the embouchure of the river or the open sea. Exceptions to this rule are in consequence of certain local conditions. One of the conditions peculiar to said formations produces the phenomenon called a bore.

The local curves which represent the laws which have to do with the rise and fall of the water at different stations are very important for the study and knowledge of the maritime region of a river. The other curves are of some importance, such as the *geometric loci of the high and low tides.* These features have been so fully discussed in the paper of Mr. Vandervin that they need not be further alluded to here.

SECOND PART.—*Application to the Weser of the principles developed in the first part under "B."*

The maritime region of the Weser extends at times of low water in the upper river from Rotesand light-house to 7 kilometers (4.34 miles)

above Bremen. It has a length of 120 kilometers (74.6 miles). *The region of the embouchure* extends from the light-house a little above Bremerhafen. It has a length of about 47 kilometers (29.20 miles). The lower limit of the upper maritime region is therefore at Bremerhafen, while the upper limit is at Habenhausen, about 7 kilometers (4.34 miles) above Bremen. See Plan I (No. 48) for these and other points mentioned. The length of the upper maritime region is about 73 kilometers (45.36 miles). At low water the *discharge* of the Weser is about 150 cubic meters (196 cubic yards) per second. Sometimes it falls as low as 100 cubic meters (131 cubic yards). The maximum volume brought down by the Weser to the sea is about 4,150 cubic meters (5,428 cubic yards) per second. Before the works of improvement were undertaken the tide at times of the strongest floods of the Weser was noticed as far as Vegesack, then about 24 kilometers (14.9 miles) below the point where this action ends to-day. It can not be stated now where the tide under the strongest floods of the river will reach, because there has been no large flood since 1881.

The limit of the flood current at low water reaches about 10 kilometers (6.2 miles) below the limit of the maritime region. At times of the largest floods of the river the limit of the flood current will probably be found 20 kilometers (12.43 miles) lower down. *The velocities of propagation* of the high tide and of the low tide have sensibly increased as the works of river correction have advanced. As a consequence the instantaneous curves of the tidal waves are considerably flattened, as will be seen by examining Plan II (No. 49).

The velocity of currents have increased in proportion to the increase of the tidal volume, but they have nowhere exceeded the admissible velocities provided for in the project. The *geometric loci of the high and low tides* before the correcting works were undertaken and those of the year 1897 have been reproduced on Plan II (No. 49). The lowering of the *geometric locus of the low tides* provided for in the project and realized as the execution of the work proceeds is of great importance on account of the increase of the volume of the tidal wave which has resulted from this lowering.

The geometric locus of the high tides has had only insignificant modifications. Further details and illustrations are given to show the important improvement in hydraulic conditions by the works of regulating the alignment and the sections of the River Weser. At some points where the river flood was contracted by closing lateral channels the congestion of the flood was relieved by energetic dredging, in order to regulate the channel and make it uniform. All of these improvements have increased the scouring force of the tidal current and river flood in a marked degree.

PAPER BY MR. J. C. RAMAER, IN CHARGE OF THE ROTTERDAM WATERWAY, ROTTERDAM.

NOTE BY THE EDITOR.—The experience which the author has had in the improvement and maintenance of the important waterway between Rotterdam and the sea makes his discussion of this subject very useful, particularly as he has used this same waterway as an illustration of his views.

A.

As informations upon a tidal river are directly useful when the engineer is called upon to make a plan for improvement, the author submits his views for this purpose. If, still further, the engineer has before him the informations upon a large number of rivers, he can, by comparing them, form a basis for developing the plan which will be the best and most economical.

The movement in a tidal river depends at the outset upon the laws of gravity, friction, and the wind. The simultaneous curve of the tide at the sea is the result of the influence of the sun and the moon. The quantity of water which passes in the river near the sea determines the dimensions of the profile of the river. When a river is, by improvement works, normalized, the flood and the ebb take about the same channel, and so unite their forces for deepening the same channel. The two elements which have the greatest influence over the movement of the water in a tidal river are the fluvial discharge and the difference between the high and low waters at the embouchure. The improvement of tidal rivers has but one purpose, and that is to deepen the channel to render it more accessible to navigation. A decimeter (0.33 foot) of increased depth in a river sometimes represents millions of profit for the cities located upon its banks. In tidal rivers which have a discharge more or less considerable coming from above the depth can be obtained by dredging, but there are two inconveniences with that method—first, great expenses, which always have to be renewed; second, the irregular bed which is left by such operations. The width of a tidal river at any point determines the depth of the channel adapted to navigation. The desideratum would be a river which would have in each part of its profile a sufficient minimum of depth and a sufficient width for the navigation, and no more. As the depth of a river is maintained by the currents, it is desirable that it should not be made to perform more work by its currents than is useful for the maintenance of the channel. However, it is necessary, on account of the results of storms making the bed of a river irregular, to give somewhat more of depth than is required by the navigation.

To improve a river it is, then, in general, necessary to narrow the bed. In general, this narrowing, when the depth is from a natural or artificial cause, does not interfere with the discharge of the water

from above. In order that the bed of the river may be as regular as possible, and the water flow as easily as possible, it is best not to build spurs above ordinary low water. There are two advantages to be attained by the narrowing of the channel: First, the tidal wave moves with more velocity when the channel is deeper, and from this greater velocity there results in general a greater movement of flood and ebb tide, and by this greater movement a greater depth can be maintained; second, the height of water, due to tempests which blow toward the land, will be less. Referring to the methods of normalizing a river, the author approves of longitudinal dikes rather than spurs, because the latter cause eddies and other irregularities in the flow, the influence of which is very bad and makes an irregular bottom. The author then proceeds to give the necessary characteristics of a tidal river. As these characteristics have been more fully stated in the two previous papers, and as this present paper was not used in the discussion before the section, it is unnecessary to go into further details.

B.

The author states that not having had the time to make a complete answer to the question in reference to "A," he will limit himself to stating some information in reference to the navigable waterway which connects Rotterdam with the sea. It is unnecessary to go into the detail in reference to the various arms of the Rhine at Rotterdam, or to review the original plans made by Mr. Caland and executed by him prior to 1878, or to discuss the modifications which a commission appointed in that year carried out. The general and detail features of the improvement are shown on Plans I and II (Nos. 50 and 51), and the results in regard to slopes, curves, and other features are shown on Plans III and IV (Nos. 52 and 53), to which reference is made for a further study of this very interesting and important work. The depths that were estimated by the commission in 1880 have been attained. This was 65 decimeters (21.3 feet) below ordinary low tide or 81 decimeters (26.5 feet) below ordinary high tide at the embouchure, and 78 decimeters (25.6 feet) below high water at Rotterdam. In fact the depths have exceeded those above stated, since in March, 1898, a ship drawing 75 decimetres (24.6 feet) passed from the sea to Rotterdam without difficulty when the tide gauge at the Hook of Holland showed 7 decimeters (2.3 feet) below ordinary low tide. At the embouchure there is dredged every year 500,000 to 600,000 cubic meters (654,000 to 784,860 cubic yards) in order to make a depth of about 15 decimeters (4.92 feet) greater than that in the interior, to allow for wave action in times of storms. At Rotterdam the depths are also greater than in the regular course of the river, as there is considerable dredging done there in order to accommodate the large number of ships that come to anchor opposite the city.

PAPER BY MR. L. F. VERNON-HARCOURT, OF ENGLAND.

NOTE BY THE EDITOR.—The entire paper of Mr. Harcourt is valuable, but as it contains 23 printed pages, and is in many particulars a repetition of what has already been stated in previous papers, only the principal parts will be enumerated.

A.

The following summary gives the various particulars with regard to a tidal river, which are of importance for determing its precise condition and for enabling its régime and capabilities for navigation to be compared with those of another river:

1. *Tidal conditions of river.*—Rise of tide at mouth. High-water lines along the river at spring tides and lowest neap tides. Low-water lines at spring and neap tides. Extent of tidal influence up the river. Simultaneous tidal lines at spring tides from mouth up to tidal limit. Volume of tidal influx at spring tides. Velocities of tidal currents in river. Height and speed of bore up river at spring tides.

2. *Fresh-water discharge of river.*—Amount of flood discharge and its average duration. Discharge at low stage and its average duration. Velocities of downward current in flood time. Influence of flood discharge on tidal flow.

3. *Alluvium carried along by river.*—Nature and amount of alluvium brought down from inland, both in suspension and rolled along the bed. Nature and amount of alluvium brought in from the sea by the tidal influx.

4. *River bed.* Nature of bed and banks. Rise of bed inland. Course of river and of navigable channel, and changes in course due to erosion of banks. Variations in depth, width, and cross section. Changes in depth, width, and cross section.

5. *Available navigable depth.*—Minimum depth in navigable channel at high water of the lowest neap tides and at high water of spring tides. Conditions of navigation.

6. *Conditions of outlet.*—Form of estuary or outlet. Exposure of outlet. Drift along the course. General condition of sea, bay, or channel in front of outlet.

7. *Bars across navigable channel of river.*—Nature, origin, and permanence of bars. Position and exposure of bars. Widths of bars at the level of the desired navigable depth.

Each of the subdivisions under the above seven main divisions are taken up and explained, and the relative importance of each stated, and its relations to the general question of obtaining information for improving tidal rivers.

The concluding remarks cover very well the points discussed, and are given in extenso following:

Several of the above particulars have been ascertained about the lower part of tidal rivers of any importance for navigation whose improvement has been contemplated, being given on the low-water charts of the river and of the sea in front of the outlet, the longitudinal section, and the lines of high and low water. To this information should be added an extension of the chart of the river up to the tidal limit, the insertion on the charts of the contour lines of depths, observations of the fresh-water discharges at different periods and of the velocities of the currents, tidal observations for simultaneous tidal lines, a series of cross sections of the river along defined lines where the river is subject to alteration, and investigations of the materials forming the bars. Moreover, in order that the condition of a tidal river may be fully understood, it is expedient that observations should be taken of the volume and nature of the alluvium carried down at different periods, of the drift along the coast in front of the outlet, and of the material brought in by the flood tide; and in order to ascertain the changes which are in operation and the prospects of the permanence or deterioration of the navigable channel, charts of the tidal river, with contour lines of depths and longitudinal and cross sections, should be made at regular intervals of about ten years and compared with the previous ones.

These particulars are important for ascertaining the condition of a tidal river and the changes it is undergoing; but it appears to the author that they are more valuable for determining the capabilities of a river for improvement, and the nature and extent of the works which should be carried out, than for merely comparing its regimen and navigable condition with those of another river. One river may possess a better channel for navigation than another, but may be much less capable of improvement owing to its physical conditions or its size; whilst the prospects of trade, which depend upon position and local considerations, exercise a paramount influence on the expenditure which may reasonably be incurred in the improvement of a river. Moreover, it would be very difficult to institute an exact comparison between different tidal rivers, owing to the numerous variable physical characteristics affecting the condition of these rivers; and even if two rivers were very similar in their existing conditions, they might still be very dissimilar in regard to their commercial position and their capabilities and resources for improvement. Nevertheless, the particulars enumerated should, as far as possible, be obtained for every tidal river of importance by their respective engineers, so that, besides forming a basis for such comparisons or contrasts as are practicable, they may furnish the exact conditions under which works of improvement are carried out, which should prove very valuable in indicating the probable results of similar works in other rivers.

B.

In order to illustrate the points discussed, the author takes two important rivers, the Húgli and the Mersey, and places the data relating to each point in parallel columns. This statement covers nine pages. The paper is accompanied by two plates (I, II), one showing the Húgli and the other the Mersey. They are Nos. 54 and 55. These plates, with sections, profiles, and curve diagrams, show the conditions of both rivers and their general physical characteristics. Some of the tidal conditions are shown on the longitudinal sections and diagrams of simultaneous tidal lines. The rapid rise of the river bed inland is also

indicated in the case of the Mersey on Plate II (figs. 3 and 5). The changes in depth and the available navigable depths are shown by the longitudinal sections of the two rivers, Plate I (figs. 3 and 4) and Plate II (fig. 5). The general course of both rivers and the form and condition of their estuaries are indicated by their general plans, Plate I (figs. 1 and 2) and Plate II (fig. 4). Following are given some of the principal conditions of these two rivers:

1. Rise of spring tides at mouth:
   Húgli, 14 feet 2½ inches.
   Mersey, 26 feet at bar.
2. Distance of tidal limit from the mouth at high spring tides:
   Húgli, 181 miles in dry season; 141 miles in floods.
   Mersey, 46 miles.
3. Volume of tidal influx at high spring tides:
   Húgli, dry season, 4,826,000,000 cubic yards; during floods, 4,080,000,000 cubic yards.
   Mersey, 710,000,000 cubic yards.
4. Maximum velocity of tidal currents per hour:
   Húgli, dry season 4 to 7 miles for the flood tide, 7 miles for the ebb.
   Mersey, 7 miles.
5. Fresh-water discharge:
   Maximum—
      Húgli, 650,000 cubic feet per second.
      Mersey, practically nothing.
   Minimum—
      Húgli, 20,000 to 50,000 cubic feet.
6. Alluvium brought down from inland:
   Húgli, fine silt and sand from the Ganges; coarse sand with silt from tributaries.
   Mersey, silt.
7. Amount of alluvium:
   Húgli, 90,000,000 cubic yards per annum.
8. Alluvium brought in from the sea:
   Húgli, none except alluvium brought down by floods and carried up again by predominating flood tide.
   Mersey, sand from erosion of coasts.
9. Changes of course:
   Húgli, although the river is of an alluvial character and is only one of the branches of the Ganges delta, it has remained remarkably stable above its estuary throughout the present century, and even in the wide estuary the deepest channel has only slowly shifted its position from time to time and has changed very little during the last fifteen years.
   Mersey, main channel through the sand banks of the upper estuary is constantly shifting its position, making even abrupt changes. In the lower estuary it has slowly altered its position.
10. Available navigable depth:
   Húgli, between Calcutta and the estuary scarcely anywhere less than 20 feet at the lowest low water of the dry season. In the estuary channel the depth is sometimes reduced at one or two places to a minimum depth of about 22 feet at high water of the lowest neap tides.
   Mersey, formerly the available depth over the bar in Liverpool Bay fluctuated in different years between 7 and 12 feet, but by dredging since 1890 there has been created an available depth at lowest low water of from 24 to 28 feet.

PAPER BY MESSRS. J. F. BUBENDEY, PROFESSOR POLYTECHNIC SCHOOL, BERLIN, AND M. BUCHHEISTER, HARBOR DIRECTOR, HAMBURG.

A.

In order to be able to characterize a tidal river and compare its regimen and its conditions of navigability with those of another river, the following facts are necessary:

1. Length of the entire river from its source to its mouth, and of the part subject to the tide.

2. The length of the section comprised between the mouth and the upper limit of the tidal influence.

3. The enumeration of the important tributaries which are subject to the tide, with a statement of the distance between the mouth of the tributary and that of the principal river, as well as the length of the tributary subject to the tide.

4. The area of the hydrographic basin above the maritime part of the main river.

5. The depth of the water from rainfall on the basin..

6. The mean annual volume in millions of cubic meters of the amount of rain which falls on the basin.

7. The mean volume in billions of cubic meters of the discharge at the upper limit of the tidal part.

8. The relation between the volume of this discharge and that of the water from rain.

9. The mean maximum and minimum amounts of water at the upper limit of the tidal section for each month of the year.

10. The relations between the discharges at the upper limit of the tidal section and the levels of the water found at that point. Draw a curve of discharges.

11. The levels of the water at the embouchure, i. e.:

a. The maximum level of the high tide observed.

b. The level of the high tide at springs of equinoxes.

c. The level of high tide at ordinary springs.

d. The mean level of high tide.

e. The level of high tide at neaps.

f. The level of low tide at neaps.

g. The mean level of low tide.

h. The level of low tide at ordinary springs.

i. The level of low tide at springs of the equinoxes.

j. The minimum level of the low tide observed.

12. The dependent relations between the volume of the tide at the embouchure and the astronomic causes, the position of the sun and of the moon.

13. The dependent relations between the phenomena of the tide at the embouchure and terrestrial causes, such as direction and forces of wind and barometric height.

14. At some important points situated between the embouchure and the tidal section the mean value of the following elements should be furnished:

a. Level of high tide.

b. Level of low tide.

c. Amplitude of the tide.

d. Duration of the flood.

e. Duration of the ebb.

f. The time required for the flood to reach the points under consideration from the embouchure.

g. Corresponding time in relation to the movement of the ebb.

h. Duration of the flood up to the moment of the turning of the current.

i. The same in relation to the ebb.

It is desirable to represent by *tidal curves* and by *curves of slope* the fluctuation in the level of the water and of the slope, as well as the points of change of the current at the places under consideration.

15. The longitudinal profile of the tidal section, showing for a great number of points the mean heights of the high and low tides.

16. A representation of the difference in the normal march of the tidal wave at the limit of the tidal part, and its rate of movement where it enters the river from the sea.

17. Volumes of water passing during the ebb in the various sections of the tidal part.

18. Modifications which these volumes undergo.

19. The widths and the surface of the river sections at mean low tide and at mean high tide at the different points between the upper limit of the tidal section and the embouchure.

20. The volumes of water passing per second under mean conditions at different moments of the ebb and flood through the sections under consideration.

21. The mean velocity through these sections at ebb and at flood, and at different moments.

22. The geological conditions of the bed of the river and of the banks and the character of the materials carried or thus deposited.

23. The minimum depths existing at mean low tide and at mean high tide, and show whether these depths are natural or obtained by dredging or created by regulation works. In the latter case it would be convenient to see what increase of depth has been caused by these works.

The authors then take up nearly all of these 23 points and give detailed explanations and describe more in detail, also, the methods of obtaining and using the information. Those points indicated by the figures 1 to 11, 14 to 17, 19 to 23, they consider absolutely necessary for the solution of the questions involved. The others, viz, 12,

13, 16, and 18, are desirable to employ when it is necessary to make a profound study of the questions.

B.

In order to illustrate the authors give facts relating to the river Elbe, taking up each one of the above figures from 1 to 23. These facts are taken from the investigations made by order of the board of public works of the city of Hamburg. Some of these illustrations will be given, the numbers on the left referring to the numbers already given under "A."

1. Length of the Elbe from its source in the Kingdom of Bohemia to its embouchure in the North Sea, near Cuxhaven (see fig. 1, No. 56), 1,141 kilometers (707.42 miles). Length of the maritime section from near Geesthacht to Cuxhaven, 142 kilometers (88.24 miles). At times of high tides caused by storms the action of the tide is felt as far as Boizenburg, 166 kilometers (103.15 miles) from Cuxhaven. During a flood in the Elbe the limit of maritime section is at Zollenspieker, 127 kilometers (78.92 miles).

3. There is no affluent in the maritime basin of the Elbe to be taken into consideration.

4. The area of the hydrographic basin of the Elbe above the maritime section is 134,541 square kilometers (51,932.83 square miles).

5. During the period of 1875–1882 the mean rainfall on the basin, per annum, was 663 millimeters (26.10 inches).

6. The mean amount of annual rainfall is about 89.3 milliards cubic meters (3,143,170,000,000 cubic feet).

7. The mean annual discharge from this amount is about 25.3 milliards (883,000,000,000 cubic feet).

8. The ratio between the discharge and the rainfall is, then, 28 per cent.

9. The zero of the gauge at Geesthacht, to which are referred the levels of the water at the upper end of the maritime section, is 5.915 meters above the zero of the gauge at Hamburg. During the period 1888–1897 the level at Geesthacht oscillated between extreme limits of −0.91 and +4.91. Diagram of figure 2 represents the frequency of the different levels of water from observations between 1887–1891. For the period 1888–1897 the mean maximum and minimum levels are shown on figure 3.

10. Figure 4 shows the curve of discharge at Geesthacht.

11. The zero of the Cuxhaven gauge is 0.066 meter below the zero of the Hamburg gauge. The highest tide observed at Cuxhaven was on February 4, 1825. It reached a height of +8.25 meters (27.07 feet).

During the period 1878–1896 the mean high tide was +4.870 meters; the mean low tide, +1.979 meters; mean range, 2.891 meters (9.48 feet).

It is advisable to adopt a period of 19 years, as this period corresponds almost exactly to 235 synodic months, being the total of fluctuation in the maximum and minimum values of the moon's declination and the variations in the moon's distance, making a complete cycle in about 19 years. Consequently this period embraces all the influences resulting from the different positions of the solar bodies. The authors then give a considerable number of details in regard to the fluctuations of the tide at different points.

12. This has reference to the dependence of the levels of the water surface and the hours of beginning of high and low tide upon each other and in reference to the position of the sun and moon.

13. No information has been obtained at Cuxhaven in reference to the barometric influence. On the other hand, there have been studied in a thorough manner the relations of dependence upon the ruling winds, for the reason that the level of the water in the bay at the head of which Cuxhaven is situated is influenced very much by the force and direction of the wind. The authors describe the tables that have been used for the purpose of showing all this data in the period from 1875–1893, and refer to figures 6, 7, and 8, Plate I (No. 56).

14. Figure 9 represents tidal curves at the following localities: Gluckstadt, 51 kilometers (31.69 miles) from Cuxhaven; Brunshausen, 71 kilometers (44.12 miles) from Cuxhaven; Hamburg, 102 kilometers (62.26 miles) from Cuxhaven; Zollenspieker, 127 kilometers (78.74 miles) from Cuxhaven. The data for this curve were obtained in June, 1886. The slopes observed represent 17 tides. The results are shown on figure 10. At Hamburg there has been noted since 1843 the levels of the high and low tide. Since 1859 the observations have been made by means of an automatic recording tide gauge. According to these observations at Hamburg, for the period of 1878–1896 the mean level of high tide was 5.099 meters; the mean level of low tide was 3.211 meters; the mean amplitude was 1.888 meters (6.17 feet). At Zollenspieker mean amplitude in the period 1888–1897 was 0.627 meter (2.06 feet).

15. In figure 11, Plate II (No. 57), is represented the movement of the flood and ebb according to observations made in June, 1886, covering a large number of points.

16. To determine the differences which exist between the different conditions of the tide, the authors give several examples which it is unnecessary to give in detail. (See fig. 12.)

17. In figure 14 are shown the volumes of water which pass during the entire duration of the flood through the different sections of the river.

18. References to the special variations in the normal movement of the tide, which are not extended.

19. Figure 13 represents the surfaces of the sections at low and at

high tide, as observed in 1886, in the lower part of the maritime section, i. e., that part where the river is divided into several arms.

20. In figure 15 is a condensed showing of the volumes of water passing through several sections from 51.3 to 115.6 kilometers from Cuxhaven. The abscissas represent the hours, and the ordinates the volumes of water in cubic meters.

21. By noticing the relation between the discharges and the corresponding sections, there can be determined the mean velocity of the current of ebb and flood tide at each hour of the tide.

22. The maritime basin of the Elbe formed in prehistoric times a gulf, penetrating deeply into the interior of the country, the banks of which are composed in large measure of beds of sand and of diluvial gravel. In course of time there were formed deposits of mud, which have formed the marshy, fertile lands, generally embanked at the present time.

23. The minimum depths in the navigable channel of the Elbe below Hamburg are in the section which lies between the mouth of the Köhlbrand and Brunshausen. The minimum depth there is 5.50 meters (18.04 feet) below mean low tide and 7.50 meters (24.60 feet) below mean high tide. These depths have been obtained by dredging, but it is believed that they will be maintained. Near Brunshausen and farther down the stream a minimum depth of 6.50 meters (21.32 feet) below mean low tide and 9.30 meters (30.51 feet) below mean high tide is maintained by natural means.

PAPER BY M. CRAHAY DE FRANCHIMONT, OF PARIS.

INTRODUCTION.

1. The problem of improving a river with a movable bed, subjected to variations of flood and ebb, consists nearly always in producing the freest possible movement to the tide in a deep and single channel. The problem is generally very complex, especially when the ports situated in the interior are at a considerable distance from the embouchure and ships of great draft reach them, for the reason that the tidal action, which is always variable, is united with the very variable action of the fluvial discharge, making variations in the general régime of the bed of the river. It is therefore essential that all these elements which are necessary for the solution of the problem should be present in a clear, methodical, and uniform shape, and that the facts should be grouped under heads universally accepted, so as not to lead to confusion or obscurity on account of incomplete and ambiguous definitions.

2. On the other hand, economical considerations do not permit generally the improvement of a tidal river, except to a limited extent, and

only where the needs of navigation demand improvement. These improvements, made in isolated localities, have often an injurious effect upon neighboring sections of the bed of the maritime part of the river. It is therefore indispensable to have along the banks of the river unchangeable reference points, in order to have a comparison of the former and new river conditions.

3. If the project in its various details follows a uniform method, so that all of its elements can be easily understood by the hydraulic engineers of all countries, it would present the advantage of making comparable the various studies made upon all the diverse parts of the maritime littoral. Also it would permit the grouping of facts in the most favorable order, both in general and particular, and so would bring valuable contribution to the study of the question of influence of the heavenly bodies upon the tides.

In meeting the questions which The Hague Congress submitted on this subject the illustration of the improvement of the Garonne below Bordeaux is brought forward and fully stated and discussed.

EXPLANATION.

4. The works of improvement on a tidal river with a movable bed can generally be classed in three divisions: The first, the improvement of the longitudinal profile of the river, or rather the improvement of the depths at those points which are so elevated as to interfere with navigation—rocks, sands, or mud, which oppose the passage of vessels and limit their draft of water. The buoying and lighting as carefully as possible is the second element of the problem in the improvement of the river.

5. It does not suffice to deepen the river by long and costly efforts, but the conditions necessary for its navigation must be so exhibited as to make it plain to the navigators how they must proceed in the channel. Therefore it becomes necessary, following an uninterrupted and prolonged series of observations, to chart the channel so completely, both in respect to the depths and the course of the channel, and also in regard to the movement of the tidal wave, as to make it possible for the navigator of a ship to know at what hour of the day or night and at what period of the lunation he will find the necessary depths at each point of the river for his vessel. This is the third point in solving this problem.

CHAPTER I.

AMELIORATION OF THE CHANNEL.

I. OPERATIONS UPON THE LAND AND OBSERVATIONS OF THE TIDES.

6. The first elements which it is necessary to be acquainted with are obtained by survey of the course of the river and establishing the

curves of its depths on plans which cover the entire extent of the maritime basin. This work requires in advance a precise triangulation and a leveling of the banks. The author then gives directions in regard to this survey.

7. The methods of leveling which are practiced on the Garonne. This river, below Bordeaux, is peculiar in that it has a very wide channel, sometimes the banks being 10 kilometers (6.21 miles) apart and the area of the estuary covering about 700 square kilometers (270.27 square miles). The work was performed by laying out on each bank, the entire distance, carefully chained lines, forming the base of a triangulation connecting the two banks. These chained lines, or bases of the triangulation, covered over 1,000 kilometers (621.38 miles). There were placed on either side permanent reference points and bench marks. Plate I (No. 58) shows the situation.

Tidal Observations and Tide Gauges.

8. The first operation above described having been finished it became possible to establish tide gauges at principal points of the river. The author then describes the various kinds of tide gauges used formerly and at present.

9. He then discusses the subject as to how far apart these gauges should be placed, concluding that it depends upon the various peculiar conditions of each river. On the Garonne there are established fourteen points of observation, about 20 kilometers (12.43 miles) apart. They are shown on Plate I. Above the maritime basin there are two fluviographs.

10. It is also desirable to accompany this installation of gauges by placing others on the opposite bank of the river to check the former.

11. The clocks of the tide gauges are then discussed, concluding that they should all be set to run together. On the Garonne they all have the time of the Paris meridian.

12. The results of the tide gauges should not be accepted without taking into account the conditions which may locally affect the movement of the tides, i. e., the variation in the barometric pressure and the effect of winds. The author gives figures to show how these two influences have affected the height of the tide at different points on the estuary.

13. He discusses the question at what elevation to establish the zero of the tide gauge, and he adopts, after discussion, that of mean low tide.

14. The results furnished by the tide gauges are not really precise without they are formed from a great number of means, and the observations should cover nineteen years, a lunar cycle.

15. Every map of soundings of the river to be clear and precise ought to give, among other informations, longitudinal profile at low

stages in the region under consideration, with references according to absolutely correct bench marks, and the relation should be shown to the low-water stage in the neighboring regions.

SOUNDINGS.

16. The method of sounding, according to the width of the river and the depths, is discussed at considerable length. The author concludes that these soundings ought, as far as possible, to be taken at the slack of the tide, either at low or high tide, and that for small depths a graduated pole should be used, but not when the depth is greater than from 5 to 7 meters (16½ to 23 feet). For wide rivers and for great depths the author recommends a sounding lead in the form of a truncated pyramid, weighing 10 kilograms (22 pounds), and the use of hydrographic circles operated simultaneously and independently by two observers placed in the same boat and looking toward the different references on the bank; the charts from these soundings to be of a scale of $\frac{1}{1000}$. On the Garonne a steel wire is used with the sounding lead.

17. The general charts of the river are, for navigation purposes, reduced to different scales and distributed among the pilots and the navigation companies. An illustration of one of these charts is shown on Plate II (No. 59).

II. TIDAL CURVES AND SECTIONS OF THE RIVER.

18. The records of the tide gauge and those of the soundings permit of making a certain number of characteristic documents. Some of these are shown on Plate III (No. 60).

19. By this means there can be determined the geometric locus of the high tides and the low tides. Fig. 2, Plate III (No. 60), shows for the port of Bordeaux the variable limit of the tidal movement.

20. The knowledge of the tides permits of the tracing at different hours of its movement the instantaneous profiles of the tidal wave, a condition which the Congress of The Hague desired to be studied and assigned to a special question. Fig. 3 of Plan III gives for the navigation channel the forms of these instantaneous profiles.

21. Another important element to be considered in the problem of improving a river is the transverse sections of the bed, considered from the point of view of the movement of the waters. This subject is, according to the opinion of the author, one of the points which, if fully studied, will give an economic and practical solution of the formation of the bed and reduce, consequently, the necessary expenses to a minimum, not only in the improvement, but in the maintenance afterwards of the depth obtained. He refers to the fact that, in most of the European rivers, the engineers are limited to the banks as they find them, on account of the country on either side being very fertile

and improved, and not capable of being changed, except at great expense.

Engineers are not in accord on the question of a rectilinear or a curved channel as being the better, the advocates of the former claiming that a rectilinear channel will allow of the better propagation of the tide, and also it would be better for navigation. He refers to the improvement of the River Weser as confirming this view, but whether theoretically the alignment should be in curve or in tangent, it will be found most generally that practically the conditions do not permit of changing the location of the channel on account of valuable property on either bank, and that consequently the only thing to do is to improve the wetted perimeter, which generally is the only part that belongs to the domain of the Government.

Hydraulic engineers of the highest authority now agree that there should be two parts in the river bed—one, the larger, which acts as a receiver for the flood tide, and which also need not be expensively rectified; the other, the smaller bed, which ought to be as regular as possible in order that the currents which move in the greater depths may find a single channel and not be liable to form a tortuous channel.

22. The information above referred to should be acquired not only upon one section, but, in order to make the channel regular and follow general laws, all the sections should be combined, and the whole force of the river applied to making a continuous channel.

23. Under this head the author shows graphically and by formula the curve of high and low tide, with the positions of the slack between them, and illustrates the subject by referring to quite a number of points on the Gironde. The sketches on Plan II, No. 59, give an approximate idea of the difference of the conditions before and after the improvement works. They show that the improvements at various points now give a draft of water for vessels descending the river from Bordeaux to Pauillac of 6.75 meters (22.14 feet), whereas, formerly, it was only 5.60 meters (18.36 feet). There will be a depth of 7 meters (23 feet) when the present improvement works are completed.

24. This is an enumeration of the documents referred to already, and are briefly as follows:

(1) A graphical chart of the widths at low stage. It will generally be useful to add to this a tracing of the width at high tide, and, by preference, the spring tides. (See Plate IV, fig. 3 (No. 61).)

(2) A graphical chart of the amplitudes of the tide at various points and under various conditions of the tide. (Plate IV, fig. 1 (No. 61).)

(3) The longitudinal profile of the navigable channel of the river in its entire length. (Plate IV, fig. 2 (No. 61).)

25. On fig. 5, Plate IV, (No. 61,) is a graphical representation of the studies made at Bec d'Ambès to establish the conditions under which the tide moves into the Dordogne, into the Garonne, and into

the false arms of Macau. This chart and analogous graphical charts of such changes furnish very interesting informations for all rivers which divide into branches.

III. CURRENTS.

26. The studies to which we have referred in a summary manner do not furnish any information upon the real regimen of the currents in a tidal river. The knowledge of this element of the problem is essential in order to characterize the different parts and give information for the benefit of navigation. To particularize, the point required is the knowledge from hour to hour of the slack of the tide. This is one of the questions very complex to solve practically. It does not suffice to know the regimen of the currents in a given region, but it should be known really at each instant of the tide, and at numerous points all the information relating to the changes. The author refers to the various registering instruments for obtaining characteristic information for determining the various elements of the currents.

IV. WINDS AND WAVES.

27. Generally these influences do not extend very far into the interior; but as we approach the embouchure of the river, and as the bed of the river enlarges, and as the materials upon the bottom become finer and more mobile, the winds and the waves begin to have an important influence, and often have a predominating influence upon the tidal currents. It is, therefore, generally necessary in a project of improvement to consider the action of the winds over the entire region exposed to their influence. On the Gironde the effect of waves from winds has been noticed as far as Pauillac, 50 kilometers (31 miles) from the embouchure. For this reason it is important to establish at proper points self-registering anemometers, giving at every instant not only the direction and the duration, but also the kilometric velocity of the wind.

28. In reference to the waves, it is necessary for the engineer to obtain information as exact as possible concerning the height and the direction of waves of storms at the embouchure of the river. The direction and force are not always in accordance with or produced by the winds which blow upon the coast. The author refers to several locations in the Indian Ocean and elsewhere where the waves are produced by winds blowing at a great distance and causing swells, sweeping around points and capes and entering the embouchures of rivers.

V. THE DISCHARGE OF SOLID MATTERS, SALTNESS OF THE WATER, AND FLUVIAL DISCHARGE.

29. The regimen of the movement of materials upon a movable bed presents, like that of velocities, a complication for which no precise

rules can be given. Various series of experiments can be made, as they have been on the Garonne. The author refers to methods of bringing up samples of water by various means in order to determine the proportion of solid matters carried by the current.

30. This refers to some unimportant conditions relating to the saltness of the water.

31. Finally, a study of the maritime region can not be complete without it is founded upon a full knowledge of the fluvial condition of the river relating to waters coming from above.

Chapter II.

The Course of Vessels in a Tidal River.

32. The problem of the proper route for ships in a tidal river assumes, for each point of this river, a knowledge of the following conditions: The depth of the bed, the local curve of the tides and the hours of reversion of the currents, and the periods of slack. These two conditions vary every hour of the lunar period and can not be known except by obtaining the mean of a great number of direct observations. This and the following numbers up to 35 present many details, showing how, upon the Garonne, the charts are prepared and how they are used by the navigators in navigating the river from Bordeaux to the sea and conversely. These charts are so complete, as will be seen by an examination of them upon Plate V, figs. 1, 2, 3 (No. 62), that in the hands of the navigator he can determine at what hour he will leave any point to go to sea or to come in from the sea, in order to always find under his keel the necessary depth of water for safe navigation.

Résumé and Conclusions.

36. The author concedes that the studies which he has discussed at such length require a great deal of trouble, perseverance, and money, yet he considers them necessary because they lead to correct plans for improvement, and also give valuable and practical assistance to navigators; and, more than that, a complete knowledge of the subject founded on the informations which he has described will assist in determining, approximately at least, the future regimen for the rectification of the channel.

It is therefore important that these studies should be taken up and followed on all rivers where there is a regular navigation service or where there is a maintenance force organized. Also that the work should be done on a uniform plan and with such expressions and terms that they will be understood by all engineers, and particularly by graphic representations. In this way the engineering and navigating sciences will be greatly benefited. The informations which are added to this paper, in the way of plans already referred to, and which

relate entirely to the Gironde, are not the result of one examination. They are the work of several years of examinations, experiments, modifications, and study.

Second question.—Modes of estimating the cube of tidal volumes. Submit and compare the analytical or graphical methods capable of determining, for any given section of a river, the flow of the tide at any moment.

PAPER BY MR. GEORGES NARTEN, HARBOR INSPECTOR, HARBOURG ON THE ELBE.

The second question, on account of the necessity of referring to divers secondary questions, is so extended and so difficult that it is impossible to treat it in a complete manner in the time at the disposal of the author; consequently there will simply be made an attempt to state, in very concise form, the analytical methods employed in gauging tidal rivers. The author refers briefly, by way of an introduction, to the effect of the solar bodies upon the waters of the oceans producing tides. These ocean tides start in midocean and, as shown by the measurement upon small and distant islands in midocean, they are hardly more than a few decimeters in height. In the neighborhood of coasts the amplitude ordinarily increases, especially where the tidal wave penetrates into an open gulf. If, now, the tidal wave penetrates into an estuary which is contracted little by little, the shape of the wave is constantly modified. It becomes less and less as it advances into the upper regions of the river, until finally it disappears entirely.

From the above it is seen at once that the discharge of a tidal river is made up of the quantity of water brought into it from the sea by the flood tide and the volume of the upper waters. It follows, therefore, that the local tidal curves change, not only from one point to another but from one day to another, according to the position of the sun and moon, and according to the force, more or less great, of the wind. The upper water of a tidal river shows, on the other hand, many persistent phenomena. Its rise and fall take place generally slowly, and are produced throughout periods of considerable length. The lines which unite the most elevated and the lowest points of a tidal wave are called, respectively, the geometric locus of the high waters and the geometric locus of the low waters. The lines situated between these two extreme lines and which, for any given moment, represent the height of the waters, are called instantaneous tidal curves. The author then makes some sketches and works out some preliminary formulæ to illustrate the above points, and from these he reasons that the calculation of the discharge of a tidal river is not as easy an operation as the calculation of the discharge of a river with a

fluvial regimen only. The methods in common use in the latter case, where the determination of velocities is the best of all researches, are not sufficient and are not always applicable, and should be applied every time with the greatest precaution. The determination of velocities by means of a current meter when these currents get below .20 meter per second are scarcely permissible, and can not be recommended when there is any other method applicable. It results from the above that the discharge of the river in a certain time and by a given profile depends—

1. On the area of the surface which is covered by the tide.
2. On the height to which the level is carried or lowered.
3. On the quantity of upper waters which are discharged into the section during the time.

The author then states two formulæ:

No. I. "$Q=\pm h.\sigma+q$" in which the surface of a portion of the river is represented by "σ." "q" represents the quantity of water brought into this portion of the river by affluents. "$-h$" represents the elevation of a water surface. "$+h$" represents the depression of the water surface. If, now, the total of all the elevations of all the parts of the river are represented by "h," and the totals of all depressions by "s," and the totals of all surfaces by "σ," we then have equation—

No. II. "$Q=\Sigma\sigma s-\Sigma\sigma h+q$."

In ordinary language, this formula No. II is as follows: The volume of water of a tidal river which, either in ebb or in flood, passes a given transverse section during a certain time, is composed of the volume of the upper waters which arrive during this time, and of the product of the surfaces which the river presents above this section, multiplied by the elevations or depressions of the surface, which are observed. The author, after considerable discussion of the subject, recommends to represent graphically all the operations made upon the river and show their results, relating to the cross sections, the areas, and the discharges. The graphic representations of these various factors will give a clear picture of the movement of the water in a river. With the method explained, which is known under the name of the "method of cubature," and on which a résumé is given in Equation II, there can be determined generally the discharge of a river into the maritime region; but if the river is divided into several arms which reunite further down stream, then the preceding theory does not suffice. There must then be a recourse to other means. The author then, as an interesting example of this kind, i. e., where the river divides into arms and reunites again, refers to the Elbe, which is subjected to the movement of the tide coming from the North Sea, and gives access to the greatest commercial port of Germany, Hamburg, and to the neighboring ports of Altona and Harbourg. The Elbe is the most important maritime

river of Germany, rising in Bohemia and discharging into the North Sea at Cuxhaven. The length of the Elbe is about 1,150 kilometers (714.5 miles). Its division into arms and branches begins below the ordinary limit of the tide. This is above Moorwerder, near Bunthaus. (See Plan I (No. 63).) Above this point for 1,038 kilometers (645 miles) the river flows in one bed. The width, up to the point of bifurcation, does not vary much from about 315 to 550 meters (1,033 to 1,804 feet) while its two branches have, respectively, 280 and 247 meters (918 to 810 feet).

The flood current extends from 30 to 50 kilometers (18½ to 31 miles) above Moorwerder. The portion of the river under tidal influence is divided into a certain number of characteristic sections, of which the most interesting are shown on Plan I. The author then gives a detailed description of these more important branches.

Even at the first half of the present century the commerce of Hamburg recognized the necessity of giving its attention to the improvement of the lower Elbe. The question of discharge was submitted to the engineer at that time. By means of Equation 1, $Q = \pm h\sigma + q$, the director of the hydraulic works, Hübbe, determined, in 1841, the quantity of water which passes in a given section of the Lower Elbe. Later this method, which is susceptible of great exactness, was often applied in the gauging of the Lower Elbe. The preparatory works for the gauging, the making of plans, and the location and establishment of gauges, as well as observations of the height of the water, have been made according to a programme more or less extensive. The last operation, taking in the entire extent of the maritime region from its upper limit to the sea, was made in June, 1886. The results which are given were deduced from tidal observations on the 21st and 22d of that month. The entire extension of the maritime region, comprising also the more important affluents of the Lower Elbe, is about 245 kilometers (152 miles), in which were established 54 gauges, an average distance apart of about 4.5 kilometers (2.8 miles). On the Upper Elbe there were placed four gauges. The location of these gauges is shown on Plan I, represented at transverse lines drawn through the points. The heights of water were noted every quarter of an hour, and in the neighborhood of these points furthest upstream every five minutes. At that time there was only one automatic tide gauge—the one at Hamburg. The observations were, therefore, made by reliable men with watches regulated and checked.

The calculation of the volumes was made by taking for the base the tide of the 21st and 22d of June, because this was very nearly at the normal mean level of tides. Plans II and III (Nos. 64 and 65) give the local curves and the instantaneous curves. Plan IV (No. 66) shows the areas of the surface and the calculation of the volumes represented either graphically or by tables. The volume of the upper waters at the beginning of the maritime section was determined by means of a

curve of discharge made for Geesthacht. The volume of these upper waters was at that time 507 cubic meters (17,906 cubic feet) per second. The volume of the upper waters of the other affluents was determined in the same way. The true point of the maritime limit was determined by a graphic representation of observations upon the gauges. Then there was made in reference to the upper part of the river—that is to say, from the limit of the flood up to Bunthaus—the calculation of volumes for each section comprised between two consecutive gauges, according to the process just indicated. At the same time, as the heights of water were observed in the sections ab and cd (see Plate I) of the plans near Bunthaus, the velocities were measured by means of a Woltman meter. These direct measures furnished the elements for the determination of the division of the volumes into the two arms. The author then gives a discussion of a formula, which need not be repeated here. The same means of ascertaining the cubature of the volumes was applied to the branches below Bunthaus as far as Blankenese.

For the determination of the volume of the Lower Elbe between Blankenese and Cuxhaven, recourse was had to the method of cubature by Equation I. Note is made that the discharge per second at Schulau, the lowest point at which observations were made, was 6,055 cubic meters (213,841 cubic feet) per second. The author emphasizes the following point as a result of the preceding discussion: That the volume of water of a river in a maritime region is determined by Equation I, known under the name of the method of cubature. If bifurcations exist, and if the volume of each arm has to be determined, then this method does no longer apply. In this case the determination of the volumes will have to be made as closely as possible by the aid of the measurement of velocities. The hydraulicians of Hamburg and of Prussia are about to undertake in common extended researches on the whole length of the maritime Elbe, and after these have been completed, a correction of the Lower Elbe from Bunthaus to the sea can then be undertaken.

The essential conditions for the study of the movement of water in a tidal river are, in résumé, as follows:

1. To unite all the stations where the gauges exist by a precise leveling, and to revise it as often as possible.

2. To use as much as possible automatic tide gauges instead of observers.

As a matter of interest the author gives what he considers to be the best kind of tide gauges, of which there are at present nine on the Lower Elbe. They are made after the system of Seibt-Fuess. A detailed description of these tide gauges is found in Centralblatt der preussischen Bauverwaltung, seventeenth year, pages 563 et. seq.

There is a note by the translator from German into French upon the value of q in the formulæ. Hübbe, the inventor of the formula of cubature, and all the others who have followed him, have desig-

nated q under the name of volume of the upper waters; that is to say, the volume of waters brought by the principal river and its affluents from above the maritime region. By means of this definition, one makes use of the very simple formula. (See formula No. II). But it is necessary to observe that the value thus attributed to q is not exact, because it takes into account only the quantity of water coming from the upper regions which pass through the section under consideration; but there should be added, also, other waters, such as those from springs which appear in the bed of the river; also its affluents below the limit of the flood tide, and this quantity can be considerable, especially if one considers that the maritime region of the Elbe has 142 kilometers (88 miles) of length. The translator, therefore, in discussing the question, adds as a factor to q the coefficient t, which is the time required for the gauging of the river.

PAPER BY M. HENRY VANDERVIN, ENGINEER OF PONTS ET CHAUSSÉES.

This paper goes very extensively into the development of formulæ of cubature, which will not be treated at length in résumé. Those who desire to study the matter in detail are referred to this paper as a valuable one for the purpose. Some of the general principles enunciated are given briefly, following: In the study of tidal rivers the principal means of controlling and determining the power of the currents which flow up and flow back in the river is found in the valuation of the masses of water which these currents displace. The course of the water has been cut by the passage of these liquid volumes. These are the factors in the creation of the channels used by navigation. They are in constant strife with the masses of material which they transport with themselves and which act as parasites upon their organism. Sometimes they are able to resist them, victoriously discharging them from their positions in the greatest depths in order to create for themselves easy avenues for their movement, and which are also at the same time most useful for navigation. Sometimes these volumes retire from before the invasion of these material matters, unable to prevent their cumbering their depths. The entire life of the river and its regimen is therefore found in this strife where the importance of the beneficent work varies in accordance with the living force of the waters; that is to say, their mass in movement and their velocity. The most direct appreciation and the most decisive of the regimen of a tidal river results, therefore, from a knowledge of these volumes of water which traverse its successive sections. The success of any modification undertaken upon the river will depend upon the quantities of water which will traverse these various sections after the work has been completed and which find themselves in the presence of analagous

quantities of solid matters. The exact valuation of these quantities of water is, therefore, of capital importance in any rational study of the present régime of a tidal river and any projects of works which it is proposed to execute upon it. The gauging of the discharges of the upper waters can generally be made easily by divers means appropriate to the conditions. It is not proposed to discuss them here. The determination as to the waters introduced or thrown out by the tide can not, on the other hand, be ascertained except by laborious cubatures, if one pretends to carry the calculations to any exactitude. The labor which this operation imposes is so very considerable that engineers often decline to undertake it, to the great loss of a correct solution to the problem. Therefore, among the desiderata which a good method of cubature ought to attain, there are placed at once *exactitude* and *rapidity* of procedure. As the data introduced into these operations relate to profiles or sections more or less distant from each other, the exactitude will depend upon the locations of the selected profiles. The more regular the course of the water and the tidal curves, the farther apart can be placed the cross sections. Rapidity should be an essential element, but it should not be obtained at the price of non-exactitude.

It is necessary to note two or three other features in the practice of this procedure. The first is the labor of preparation and the union of the elements which will have to be used in the cubatures. The second is to make the collection of data so extensive and complete in all the sections that the volumes flowing can be easily ascertained. The third part is the study of the modifications projected. The hypothesis in which the cubature is to be effected having been determined by the engineer, the operation itself need not require any further reasoning, and ought, consequently, not to uselessly absorb the time of the engineer. It is important, therefore, that all the calculations should be simple.

The modes of cubatures employed by engineers formerly, who attempted to give a valuation to the volumes of water traversing a given section in a tidal river, were very rudimentary. In place of instantaneous curves they considered only the geometric loci of the high tides and the low tides, and calculated the volume comprised between these curves. The engineers who have followed them have considered more precisely the volume of the flood and of the ebb limit curves corresponding to the slacks of the tide. In order, therefore, to obtain better knowledge of the variations of discharge at the different times of the tide, evaluations are made of the volumes comprised between the instantaneous curves relating or referring to moments of time more or less close, from hour to hour, for example. Sometimes there has been substituted for the real bed a fictitious prismatic bed of a width equal to the mean width of the river. After discussing the

formation of a formula to meet this case, the author refers to figs. 1, 2, and 3 (No. 67), showing a comparison of results obtained by the application of one or the other procedure upon tidal rivers in Belgium.

In the cubatures of the tidal volumes in the Escaut (Scheldt) and its tidal affluents the engineers have introduced wet sections for the purpose of permitting these processes of cubature to be sufficiently rapid, and in the work of preparation they can, by making for each cross section under consideration a curve of surfaces, give the wet section for every height of water. The section has thus been divided at once into two parts, separated by a horizontal AB (see fig. 4, No. 67), placed at the level of the low waters to be considered. The lower part, ACB, corresponds, therefore, to a smaller bed always filled with water, and the surface, ACB, is a constant in the entire wet section, whatever may be the level of the water. This section is calculated, once for all, exactly by the aid of ordinates furnished by the soundings. The author then develops, through several pages, his various formulæ, which refer more or less to the various figures on No. 67.

PAPER BY M. M. CRAHAY DE FRANCHIMONT, ASSISTANT INSPECTOR-GENERAL OF MARITIME WORKS, PARIS.

The problem of the reception or the discharge in a given time of a determined evaluation of volume of the tide above or below one of the transverse sections of a river or of an estuary is one of those problems which engineers have most often and most naturally to consider, because its solution permits them to value the hydraulic power of the river characterized either by the importance of its instantaneous or total discharge, or by the importance of the quantities of movement or of living forces developed by the circulation of masses of water corresponding to this discharge. This problem can be resolved in two different ways, either by the phenomena which are found in a given section, or by those which are produced simultaneously by virtue of the incompressibility of the waters in the entire extent of the bed above that section. In the first case the solution is obtained by direct gauging. In the second, by means of geometric cubature, where there ceases to intervene the consideration of the velocity of the liquid fillets, or where there needs to be considered only the volume received into the bed of the river or discharged from it in a given time. From another point of view the problem presents itself in a different way. When one undertakes the study of a tidal river he perceives very quickly that all the elements of this study have not the same value. If, for example, the consideration of the present or future discharge has great importance in the complete amelioration of the river, or of an estuary which has been obstructed for a long time

by deposits, which have, so to speak, abolished the propagation of the tide, this same consideration loses much of its value when in a river like the Gironde, or even like the maritime Garonne, the deteriorations of the regimen are only local, and the ameliorations to be made are without sensible influence upon the increase or the decrease of the tidal discharge.

It is necessary on most rivers that there should be established in the first place fixed reference marks for comparison, in order to determine the relative errors of different methods of calculation. How advantageous it would be to-day to possess with any approximation the volumes of the tide which passed in the seventeenth and eighteenth centuries in front of the most notable stations of the maritime Gironde, at the embouchure at Pauillac, at Bordeaux. One would know in this way, by comparisons of the successive periods, the degree of age of the river, if one may say so, and certain tendencies of the régime would appear quickly, which could not be undersood to-day on account of the investigations and the observations being very recent. The considerations and the calculations which are to follow are intended to develop the above observations. They are the résumé of studies undertaken under the direction of the author from 1882 to 1896, and principally due to the work of MM. Volontat and Vidal, ordinary engineers, and of M. Lanave, of Ponts et Chaussées at Bordeaux. The first part is an explanation and a criticism of the methods adopted. The second gives in some numerical tables some of their particular applications.

Part I.

Inspection and Criticisms of the Methods Adopted.

I. *Object of the problem.*

The problem of the cubature of tides in a river or an estuary subjected to the play of the tides is stated under one of the two following forms:

1. To deduce from the dimensions of the river or of the estuary and from the elements observed defining the propagation of a tide of a given coefficient, the discharge which at any instant of this tide traverses a definite section, whether moving up the river or down.

2. To deduce from the same elements the volume which enters the part of the river above the selected section or is discharged below it in a given time.

II. *Method by direct gauging.*

The first solution of the problem consists simply in making at the section under consideration a series of direct successive gaugings during the duration of a flood or an ebb. The measure of the velocities related to the measure of the heights of water permits the determination of the wet section at each instant and furnishes immediately

the instantaneous discharges at the hours of the successive gauges. This process requires to put at work a personnel and instruments quite numerous according to the character of the section. The direct observation of velocities is always delicate. This system has been employed but little in France. The author then cites several examples where it has been used. For instance, in the Basin of Aracachon, which is a vast interior estuary (fig. 1, Plate I (No. 68)), 15,000 hectares (37,068 acres) in area, connected with the Gulf of Gascogne by a narrow strait or pass. It is generally filled up with reefs and bars, entirely covered at high tide, but all emerging at low tide; between each circulate sinuous channels of very irregular depth. The depth of water below low tide varies from 1 to 15 meters (3.28 to 49.21 feet). The arrival of the flood at any given point is generally by two different routes. In a profile to be studied (fig. 2, Plate I (No. 68)) there has been arranged a certain number of stations of observation formed by anchored boats. At each one of these there is measured periodically the mean velocity of the corresponding part of the channels. In such a case as this there are used loaded staffs arranged in such a manner that their loaded ends will always be about one-half a meter above the bottom and the course followed by them is noted every half minute. The section is supposed to be divided into parts by the verticals Aa Bb dividing into equal parts the distances 1-2, 2-3. Supposing "V" to be the mean velocity obtained at station 2, for example, at an hour t corresponding to a height y of the tide, l to be the width of the part AB and S the area in this part below low tide. The instantaneous discharge q of the part Aa Bb at the hour t will be $q=(S+ly)\,V$.

III. *Methods based on the making of instantaneous sections—General formula.*

Outside of direct gauging the methods employed are based on a comparison of the existing volumes in the river above the section chosen at two instants separated by an interval of time. Their difference gives the total discharge which has traversed the profile during this time. One can establish in the following manner the general relation between the two total volumes successively presented in the bed of the river. It furnishes the complete solution of the problem. The author then refers to figure 4, Plate I (No. 68), and, further on, figures 5 and 7, and works out by a lengthy calculation the necessary formulæ.

V. *Complete arithmetical calculation of the total tidal discharge.*

The direct application of the formula which he has previously stated allows an immediate calculation of the total discharge passing in the flood during a tide and through a given section.

VI. *Instantaneous discharges and velocities deduced from the arithmetical calculation.*

The remaining points discussed at length are:

VII. *Simplifications of the arithmetical calculation.*

VIII. *The expeditious calculation of the total discharge.*

IX. *The complete graphical calculation.*

X. *The comparison of the numerical and the graphical calculation.*

The author, in conclusion, states that the results arrived at by these various processes would depend upon the precision with which the data are given and stated.

Third question—Means of consolidating ship-canal banks.—Complete the information furnished at preceding congresses and relate the experiments made, dwelling upon the nature of the soil and conditions of navigation (speed, extent of traffic, mode of propelling, relation between the wet section of the canal and boat, etc.). Outlay for first establishment and cost of keeping in repair.

PAPER BY M. L. GRENIER, PRINCIPAL ENGINEER OF PONTS ET CHAUSSÉES, GHENT.

This paper comprises twenty-five printed pages, divided into five chapters, and relates almost altogether to the ship canal from Ghent to Terneuzen, in Holland. The following comparatively brief résumé will no doubt suffice:

INTRODUCTION.

GENERAL CONDITIONS.

The problem of the consolidation of the slopes of maritime canals is of great interest and demands the attention of the powers that be. In fact, upon its proper solution depends, in great measure, the conservation of artificial waterways, and consequently this solution exerts an important influence upon the security of navigation. As the works, to secure the slopes, require the expenditure of a large amount of money, it is important that this expenditure should be as useful as possible. Besides, the problem becomes daily more difficult on account of the increase in size of ships and in their speed. For this reason the question has not ceased to interest the most experienced engineers and preceding Congresses. After the lengthy studies which have been given to the question, the author thinks it would be risky to discuss the subject in any other way than to relate the actual facts of experience. He has charge of the maintenance and improvement of the Belgian part of the international canal before mentioned, and as such he has been able to obtain many facts which he contributes to the question.

EXAMINATION OF THE QUESTION UNDER DISCUSSION IN REFERENCE TO THE GHENT-TERNEUZEN CANAL.

The conditions are as follows:

1. *The absolute or relative impossibility of increasing the wet section.*—The canal traverses a region which is absolutely furrowed with roads and railroads, with important settlements covered with properties of great value and numerous industrial establishments along the banks of the canal. The line is too costly to increase the wet section by widening the canal.

2. *The easy and rapid sloughing off of the banks.*—The land which the canal traverses is very movable, and, on account of the short time allowed for lockages at Terneuzen (about five hours by the tide), the speed of ships often exceeds that allowed on similar canals.

3. *The traffic is both maritime and inland.*—The tonnage of the former in 1897 was 1,208,477 registered tons, entrances and clearances; the latter, 342,022 tons of weight. Therefore the consolidation works must satisfy the demands of a considerable maritime traffic of great speed and must not injure the interior navigation.

CHAPTER I.

SUMMARY DESCRIPTION OF THE CANAL.

Dimensions.—Width at bottom, 17 meters (55.76 feet); inclination of the slopes, 3 to 1; depth, 6.50 meters (21.33 feet); wet section, 237.25 cubic meters (2,554 square feet).

Nature of the soil.—The canal is cut entirely through sand extremely movable, and sloughs off with the greatest facility.

DESCRIPTIVE CHARACTERISTICS OF THE TRAFFIC.

A. Speed.—The speed for ships is fixed by rule at 10.8 kilometers (6.7 miles) per hour, but a much greater speed has been allowed, sometimes exceeding 12 kilometers (7.45 miles).

In a footnote the author gives some useful information in regard to speed on canals:

Ghent-Terneuzen:

15 kilometers (9.32 miles) per hour for a draft 1.50 meters (4.92 feet) and less.
12 kilometers (7.45 miles) per hour for a draft 1.50 to 2 meters (4.92 to 6.56 feet).
10.2 kilometers (6.21 miles) per hour for a draft 2 to 2.75 meters (6.56 to 9.02 feet).
8.7 kilometers (5.40 miles) per hour for a draft 2.75 meters (9.02 feet) and above.

Amsterdam Canal:

15 kilometers (9.32 miles) per hour for a draft 1.50 meters (4.92 feet) and less.
12 kilometers (7.46 miles) per hour for a draft 1.50 to 2 meters (4.92 to 6.56 feet).
9 kilometers (5.59 miles) per hour for a draft of more than 2 meters (6.56 feet).

Loire Canal:

9 kilometers (5.59 miles) per hour.

Kaiser Wilhelm Canal:
10 kilometers (6.21 miles) per hour.
Suez Canal:
10 kilometers (6.21 miles) per hour.
Manchester Canal:
About 11 kilometers (6.83 miles) per hour.

The great speed of the Ghent-Terneuzen Canal is only in straight reaches. On the remainder of the canal, where there are short curves, it is only about 6 kilometers (3.73 miles) per hour.

B. Modes of propulsion.—Altogether by screw.

C. Intensity of traffic.—This is steadily increasing from about 500,000 tons in 1884, with a mean tonnage of 320 tons, to 1,208,477 in 1897, with a mean tonnage of 617. The steamers vary from 400 to 1,000 tons, and it is these steamers which cause the greatest injury to the banks, as they are often obliged to accelerate their speed so as not to disorganize their service.

Ratio between the wet section of the canal and the immersed section of the vessel.—The latter is about 40 square meters (430 square feet), the wet section of the canal being 237.25 square meters (2,554 square feet) and the ratio 5.93. It is well known that the Congress of Vienna fixed 4 as the ratio of inland canals and 6 for maritime canals, as maximum. The large steamers have an immersed section of 60.5 square meters, which makes the ratio 3.9, even less than that allowed for inland navigation.

Chapter II.

Historical Résumé of Efforts to Consolidate the Banks.

1. *Description of these various systems.*—Previous to 1885 the work was limited to placing broken brick covered with stone upon the slopes, and this was only for the part under water. Above the water strong soil, well rammed, was used and covered with turf. Since 1885, upon the development of steam navigation, there was adopted a vertical revetment, which consisted generally of a continuous row of old railroad ties which came above the surface of the water sufficiently to connect them by a longitudinal plank. Behind these ties the existing excavations in the slope, up to 0.7 meter (2.30 feet) above the level of flotation, were filled with broken brick and stone. In 1893 this system was abandoned to return to the former, modified in this, that the rock slope was composed entirely of broken stone.

2. *Cost of the systems.*—The cost of the second system, up to 1893, averaged 10.84 francs per running meter (66 cents per running foot).

3. *Results obtained.*—The enrockments on the slope have not given good satisfaction. As to revetments by old ties, the slope, not having been consolidated previously, suffered a great deal, and this slope

extended a considerable distance into the canal, nearly 9 meters (29.5 feet) from the alignment of the revetment.

The writer gives under this heading several tables to show the effect of the waves of passing steamers at different depths, the general result being about as follows:

The first table gives the information in a general manner in reference to all of the sloughing off found along the canal, without distinguishing those parts on which the navigation is at great speed from those parts along which there is a reduced speed. The conclusion from the tables is that about 73 per cent of the wasting away of the slopes is found between 0.50 meter (1.64 feet) above and 1.25 meters (4 feet) below surface. Again, he compares the effect of waves upon bermes that are consolidated and upon those that are not, and the table shows that in the former case there is 78 per cent of the injuries below 1 meter (3.28 feet) and 46 per cent of bermes not consolidated, showing that if it is desirable to obtain bermes at such a depth it is indispensable that they be consolidated. He gives other tables to show the conditions, with the following general result, and that is that nowhere have there been found injuries to the slopes below a depth of 2 meters (6.56 feet), even upon bermes that are not consolidated and in that part of the canal where the navigation is the most rapid.

CHAPTER III.

EXAMINATION OF THE DIFFERENT PRINCIPLES OF THE CONSOLIDATION OF THE SLOPE OF THE GHENT TERNEUZEN CANAL.

This chapter comprises a description of the various systems proposed and of that which has been definitely determined upon.

Plate I (No. 69), with several figures, shows the methods that have been proposed, and fig. 8 shows the method finally adopted after the experience of many years. An examination of these figures will make further description unnecessary, except to refer to fig. 8. It may also be stated that fig. 6 shows the method adopted in Holland.

CHAPTER IV.

GENERAL CRITICISM OF THE VARIOUS TYPES DESCRIBED WHICH ARE COMPREHENDED IN TWO DIVISIONS, THAT OF SLOPE REVETMENT AND THAT OF VERTICAL REVETMENT. THE AUTHOR DISCUSSES THEM FROM SEVERAL POINTS OF VIEW.

1. The cost of the construction.

2. The advantages and inconvenience of each system in reference to maintenance and repairs.

3. The comparative practicability and convenience of increasing ultimately the section of the canal.

4. The influence of the transverse profile upon the resistance to ships in transit. The author then gives a description of the various causes which operate to destroy the revetment of a bank.

The movements of the water are twofold:

1. That flowing past the ship and parallel to it and the bank, caused by the motion of the ship through the water.

2. The action of the propellers, which produces a gyratory motion, attacking the banks obliquely and having a tendency to withdraw the earth from behind the revetments.

The expenses of the first establishment.—From facts already given in the report, he is of the opinion that they demonstrate that it is fully as costly to protect slopes as to build a vertical revetment. Also that the latter, if necessary, can be built without lowering the level of the water, and he is also of the opinion that the canal can be more easily widened and deepened with a vertical revetment than with slopes. He combats the idea held by many engineers that a berme is necessary to reduce the action of waves, his argument being that if the berme is established below the action of the waves it loses the importance attributed to it and is unnecessary for that purpose, and if it is above the level where the waves make themselves felt, then it is liable to be cut into and wasted away. Also, if it is considered necessary for the holding of the slope above it, it would still have to be cut away in widening the bed of the canal.

The author then takes up the question of the influence of the form of the transverse profile upon the movements of vessels, and brings forward facts from other canals, particularly the Suez, and from discussions in reference to current, to show that the agitation caused by waves diminishes as the banks approach the vertical, and mentions an example where the resistance of the rectangular profile was 25 to 30 per cent less than that with a profile in trapezoidal form. His conclusions upon this important part of the subject are:

1. The establishment of revetments upon the slopes is at least as costly as that of vertical revetments.

2. The works of maintenance and repairs of revetments of the former type cause either very great accessory expenses or the suspension of the navigation. The works for the maintenance and repair of vertical revetments are very easily performed, and do not interfere at all with navigation.

3. Revetments upon the slope prevent, except at enormous expense, future enlargement of the canal. With vertical revetments this enlargement can be made without large expense.

4. A vertical revetment presents less resistance to the movements of vessels. The author formulates a proposition to be submitted to the congress approving of vertical instead of sloping revetments.

CHAPTER V.

CONSIDERATION OF THE PROPER MEANS TO INSURE THE IMPERMEABILITY OF VERTICAL REVETMENTS.

He rapidly reviews the methods mentioned—

1. By tongued and grooved sheet piling, which is used a great deal in the Low Countries.

2. The best means of consolidating the earthwork behind revetments—and refers to the decision of the congress at Paris, where it was proposed to place a béton of sand behind these revetments of a thickness of about 35 centimeters (13.8 inches), which has been used with great success on the Kaiser Wilhelm Canal. This method of construction could be easily applied, and with little expense, as it is formed of nearly pure sand, because the transformation of the sand behind revetment into béton could be made by the injection of cement by means of compressed air. He then describes a method of revetment in béton entirely (béton armé), which was brought forward by M. Hennebique, contracting engineer.

Plan II (No. 70) gives all the details of a revetment of this kind. It is composed essentially of a screen of sheet piles formed of béton and of iron, so arranged by semicircular grooves that they fit like similar constructions in wood. The plan above referred to shows the method fully, and it need not be further enlarged upon. It is really the same system as that of fig. 8, Plan I, except that the former is in wood and the latter is in béton. This plan can be carried out, both in construction and in maintenance as well as in repairs, without lowering the water in the canal. The minister of agriculture and of public works in Belgium, recognizing the merit of the plan, has decided to make an attempt along the Terneuzen Canal on a length of 100 meters (328 feet). This experiment will show—

1. Whether it is practicable.
2. The exact cost.
3. Whether it will make the embankment behind it permeable.
4. Its resistance to shocks or friction of inland boats against it.
5. Whether, if it is injured by a ship running against it, it can be repaired.
6. To make experiments upon the special resistance to flexure of each of the parts constituting the system.

PAPER BY MR. FÜLSCHER, GEHEIMER BAURAT AT THE MINISTRY OF PUBLIC WORKS, BERLIN.

The observations in this paper relate to the works of bank protection employed in the construction of the Kaiser Wilhelm Canal. At the time the project of the canal was formed there had been planned

ashlar masonry on a bed of gravel or broken stone, at points exposed to the action of the waves. Revetments of the kind had been often employed with success in the protection of river banks, against the sea on the German coast of the Baltic. An approximate estimate of the amount required was about 600,000 cubic meters (784,770 cubic yards). Since from the excavation of the canal there was found only a small amount of rock, it followed that the larger part of the stone would have to be brought from a distance, to be procured only with great care and at great cost. From this fact the question arose, if there could not be recourse to some other kind of materials. Among artificial materials the first to which attention was directed were hard bricks, and then sand béton. The sand necessary for the mixture could be obtained in the excavation not very far distant from where it would be used, but there was not sufficient experience in reference to brick revetments or of sand béton to be able to say with certainty whether they would be effectual or not. Therefore experiments were made.

Two years before the commencement of the works an experiment was made, in 1884, to protect a small part of the bank of the old canal of the Eider by means of masonry formed of brick laid on edge, resting on a bed of gravel. This revetment held well, both above and below the water surface. Other pavements and brick of a different construction, as well as revetments of broken stone, were made in 1889 along the same canal for the purpose of determining the kind of brick masonry which would be the best, and to ascertain if there could be substituted for stone or brick masonry revetments formed of beds of gravel and of broken stone. At a dozen points brick masonry was constructed on a slope having 1½ to 2 of base to 1 of height. These brick were laid with courses sometimes parallel, sometimes perpendicular to the bank. They were sometimes of one brick and sometimes of half a brick in thickness. They rested on a bed of clay, of gravel, of coarse sand, or of fine, pure sand. On account of the heavy traffic at that time through the canal these revetments were exposed to very severe action of waves. Settlements were produced very shortly with masonry laid on sand, because the sand was drawn out through the joints of the pavement. On the other hand, revetments on clay and on gravel held very well, except when gravel was too fine or not well rammed. Half a brick in thickness seemed to serve about as well as an entire brick. These experiments led to the following conclusions:

1. One can protect in a durable manner the bank of a canal having a slope of 1½ to 2 of base to 1 of height by means of brick masonry having a thickness of one brick or half a brick.
2. It is recommended to place the courses parallel to the bank.
3. Whenever the bank is formed of strong earth or clay it is safe to

place the bricks directly on the slope, making the joints as tight as possible.

4. On the contrary, when the bank is made of sandy earth, it is necessary to place the brick masonry on a bed of gravel of a thickness of 0.15 meter (0.5 foot) or 0.10 meter (0.3 foot) or of 0.05 to 0.06 meter (0.16 to 0.19 foot) according as the earth is of pure sand, of clayey sand, or sandy clay. The experiments in broken stone have given equally good results. When the slope had an inclination of two of base to one of height it gave good results, but it did not hold well when that inclination reached 1½ of base to one of height. These experiments have also shown that it is well not to give to the beds of broken stone less than 0.45 to 0.50 meter (1.5 to 1.6 feet) thickness, and that to prevent the washing of the banks, which is necessary, the lower bed of the revetment should be formed by materials of lesser size, that is, of gravel, grains of which should be from 2 to 30 millimeters (0.08 to 1.18 inches) in diameter. At the surface it is useful to employ rubble stone weighing from 2 to 10 kilograms (4.4 to 22 pounds) and to select the most angular possible, in order that the stones may not be drawn out by the movement of waves. Irregular blocks which are quite rounded ought to be broken at least once. The first experiments with sand béton were made on parts of the canal, cut in the dry. In July, 1889, there were built blocks of sand béton with proportions of 1 to 10 and of 0.25 meter (0.82 foot) in thickness, of such a length and width that it required at least two men to move them. The joints between the blocks were disposed in such a manner as to permit the discharge of the water which had penetrated under the revetment, and to prevent the running out of the sand from the bank. For this purpose there was given to the blocks the length of 0.56 meter (1.86 feet), and a width of 0.46 meter (1.5 feet). Two of the lateral faces were given a tongue and two others a groove, as shown on figs. 1 and 2, Plate I (No. 71). These blocks were formed in light wooden boxes, which could be easily taken apart. These blocks are shown on the above-named figures. This method was quite costly and inconvenient, on account of the great number of molds and of machines which it required, as it was necessary to retain them in the molds until the béton had become fully set. Afterwards this plan was given up and the slabs of béton were built immediately upon the banks.

The author then describes the method of doing this and refers to figures 3 and 4 for an illustration. At first, after the blocks had been well set, a bed of fine béton was put on with a trowel, but this did not work well, as it would not unite sufficiently with the original block and there was often a considerable exfoliation. In order to diminish the expense the thickness of the blocks was brought down to 0.20 meter (0.6 foot); these cost from about 4⅛ to 5½ francs per square meter (72 to 91 cents per square yard), according to whether the sand

was found conveniently or had to be brought from a distance. The low price of this work led to its adoption below the water rather than to use ashlar masonry or brick masonry. Béton revetments do not resist the action of the air, consequently they should not be employed above the water. As to the materials to use above low water, the choice depends on the nature of materials which one has at disposal as well as the means for working them up. For brick masonry the bricks were clinker bricks and the irregular blocks of granite were taken either from the canal itself or were brought from the Baltic. The ashlar, sandstone, and granite were brought from the quarries in Saxony or from the basaltic quarries on the Rhine. Most of the materials to be placed under the masonry were found along the line of the canal or near it. The bank revetments to which recourse was had in different sections of the canal may be classed under five types, of which the cross sections are represented by figures 5 to 9. Figure 5 shows masonry entirely of brick, and it was used on one section of the canal where the sand necessary for béton could not be brought to the work except at great expense and where the bricks could be obtained at a very low price. Figures 6 and 7 show revetments of which the part under low water consists of slabs of sand béton, and of which the part above low water is paved with brick or ashlar. As the figures show, the slabs of béton were placed generally upon the banks after they had been dressed smoothly or had been covered with a fine bed of sand. These slabs being nearly impermeable made it necessary to arrange for water from springs to be allowed to run out without injury to the slopes. In places where during the construction of the slabs the water exuded along the banks in such a quantity that it could not be expected to dry up it became necessary to place the revetment on a bed of gravel for the water to filter through. In view of greater security, in nearly all these cases béton revetment was given up and there was substituted in its place a bed of broken stone or of masonry. At other places where the discharge from springs was very moderate there were placed drains for carrying off the water. Revetments of béton described above have generally been found very successful. In one section, however, it was noticed, even during the construction of the works, that many of the slabs had hardened only at the surface and that a year afterwards the lower part was still soft and pasty. This was due to the fact that they were laid upon turf and other soil where there was a discharge of organic acids, which had a tendency to unite with the chalk of the cement in such a way as to make soft soap.

The parts above the water, built with the revetment described above, have endured very well, whether of stone or brick. There have been noticed damages only at points where the stone or brick were laid directly on the bank or on a bed of too fine gravel, and at some points where the stonework rested directly on large size gravel found in the

excavation. Figures 8 and 9, Plate II (No. 72), show revetments built entirely or partially of broken stone. This material was used on sections of the canal where the banks could not be completed until after the canal was filled with water. On slopes to be covered with broken stone there was given an inclination of two of base to one of height for reasons above stated. Everywhere there was given to the bed of broken stone a thickness of half a meter. The profile of figure 9 shows an "avant-berme" in broken stone 0.25 to 0.30 meter (0.82 to 0.98 foot) thick, which was laid partly before and partly after the construction of the bank protection. This was added for the purpose of increasing the resistance of the foot of the masonry. In sandy lands, as at dikes formed by sand, turned into peat bogs, and on long sections of a canal in the valleys of Geiselau and Eider, the revetment is made in three beds, as shown in figure 8, the lower bed of gravel with grains of 2 to 30 millimeters (0.08 to 1.18 inches) in diameter or of heavy sand mixed with small broken stones, a middle bed of gravel of 10 to 120 millimeters (0.4 to 4.7 inches) in diameter, and upper bed of stone, the volume of which ran from 5 to 8 cubic decimeters (0.176 to 0.282 cubic foot). Figure 9 represents a revetment of which only the part under low water is built of broken stone, and of which the upper part is formed of stone masonry. This was employed in a basin of the old canal of the Eider everywhere where it was impossible to make the slope in the dry.

As to the complaint heard from different sources that the salt water of the Baltic Sea passing into the canal would exercise a destructive action upon the béton slopes, it may be stated that up to the present time there is no indication that that apprehension was well founded.

All of the works of protection above described can be recommended wherever the circumstances and the materials are like those presented at the Kaiser Wilhelm Canal. After the experience required we have to say further, that it is necessary to watch—

a. At the time of the construction of the revetments in béton slabs that these slabs are protected as much as possible against the action of ice, and that the waters from peaty soils charged with organic acid should not penetrate the béton, and that by the aid of drains, and if necessary by the aid of a bed of gravel, the waters from springs should be allowed to run off under these slabs in such a manner as not to injure the banks.

b. At the time of the construction of brick masonry on banks of sand or of clay or of sandy earth, that the masonry should rest on a bed of gravel, preventing the washing of the slopes through the joints of the bricks.

c. At the time of the construction of ashlar masonry or by split irregular blocks placed on sandy banks, that the masonry should rest not only on a bed of materials sufficiently voluminous, into which the ashlar is placed—gravel, broken stone, or briquettes—but still more on a lower bed of clay or gravel, about 0.10 meter (0.33 foot) thick.

d. At the time of the execution of the works in broken stone, though in the case of banks of sand, this bed of clay or of gravel should not be lacking.

PAPER BY MR. P. E. GERHARDT, KÖNIGSBERG, PRUSSIA.

The facts given in this paper relate to the maritime canal between Königsberg and Pillau, passing through the Frisch-Haff. Königsberg is a city of 180,000 inhabitants, the most important commercial center in the east of Prussia. It is situated on the Pregel (see fig. 1 (No. 73)), a river which is accessible to seagoing vessels. The Haff forms a basin of fresh water, having a length of 80 kilometers (49.7 miles) and a width varying from 8 to 32 kilometers (4.97 to 19.9 miles), into which empty several large and some small streams. Further descriptions are shown in the figure above referred to. The depths are as follows: 6 to 13 meters (19.7 to 42.6 feet) in the Pregel, 8 meters (26.24 feet) in the Pillauer Tief, while in the Haff it reaches 4 meters (13.12 feet) only in the center. Near the banks the depth is very little. The depths through the Haff have been increased, but in order to provide for larger vessels up to Königsberg it was decided to construct a maritime canal. This canal will cost 12,300,000 marks (₹2,952,000). It consists of a dredged channel from the embouchure of the Pregel along the north bank of the Haff to Pillau. It crosses in its course the lateral Haff shown on the map. The cross section of the canal is shown on figs. 4 and 5, Plan II (No. 74). The width at the bottom is 30 meters (98.4 feet). The depth at the mean level of the water is 6.50 meters (21.32 feet), and the slopes are 1 to 25 in the sandy soil and 1 to 5 in mud. In the curves the width is increased according to curvature. On the two sides of the channel there have been established banquettes 25 meters (8.2 feet) wide at a depth of 2 meters (6.56 feet) under the mean line of flotation. These banquettes are for the purpose of preventing the filling up of the canal with sand, and also to serve for a passage over them of small fishing boats and other craft of light draft in order to keep them outside of the canal devoted to ship navigation. The length of the canal from Pillau to the embouchure of the Pregel is 32.5 kilometers (20.19 miles), and the whole length to Königsberg is 45 kilometers (27.96 miles). Dikes (see fig. 1, Plan II (No. 73)) have been built wherever the canal is near the bank of the Haff. They serve to protect navigation and the navigable channel against the waves, against silting up, and the ice. A double range of piles (see fig. 3) is driven with an inclination of 1 to ¼, at such a depth that the heads of the piles remain about 0.8 meter (2.62 feet) below the mean level of the water. High water at Pillau does not rise more than 0.94 meter (3.08 feet) above the mean. These piles are about a quarter of a meter in width, and a length of from 4 to 7 meters (13.12

to 22.96 feet). The distance between the heads of the piles is about 1.5 meters (4.92 feet). The bottom of the Haff on the line of the dikes has been raised by means of materialsfrom dredging up to 0.80 meter (2.62 feet) below the mean level. Behind these dikes, by means of earth from the dredging, there has been built an embankment. It was done by means of dredges, the pipes of which were extended up to 600 meters (1,968.5 feet) in length. This material thus forms an outside bank with a very flat slope. The bottom is composed of fine sand, mud, marl, and clay. The sand is of very fine grain. To prevent this fine sand from running through the openings of the piles and the stone used for ballast there was nailed to the outside of the piles "Hessian cloth." This was sufficient to prevent the movement of the diluted material into the channel. Afterwards, when the aquatic plants had taken root on the slopes of the dike, it was allowed to go into decay.

Without going into further details of the method of completing the works, it is sufficient to refer to the main object of the paper, which is to illustrate the method of protecting these slopes by means of various aquatic plants. These are shown on the figures of the plans (Nos. 73 and 74). There are two kinds of rushes used which will grow under water, viz, the "scirpe" and the "jonc." These plants were used both outside and inside of the dikes. The latter class is carried to about half a meter above mean low water, and above that point reeds of a larger growth are used, and still higher there is used a class of willows, "osier." Various means of setting out these plants and trees, of pruning them, and other such features are given in description, and their locations are shown on the plans. The most important plant for such purposes and in such locations as the works herein described is the "jonc." The botanical name of this is "Arundo phragmitea." This forms, with its stiff stems, an excellent protection against the waves. Its roots push themselves strongly into the soil and extend laterally in every direction. It propagates itself with such vigor that, in the depth of water which is suitable to it, it soon supplants the "scirpe" and the "roseau" and reeds. On account of its excellent qualities great attention and care have been given to its culture. It grows best in the sandy soil, mixed with marl and mud, but it will grow well on sandy soil alone. It grows in water to a meter in depth, and even to a meter and a half (3.28 to 4.92 feet), but it also grows up to half a meter above mean water. It will grow in brackish water as well as fresh. Its roots go down to a depth of 5 to 10 meters (16.4 to 32.8 feet) into the soil, and it extends in every direction in such a way as to make a complete network. On the bank and at slight depths of water the roots penetrate slightly into the soil, but at a greater depth they form a bed of felt, as it were, which floats in the water. At low water this bed rests on the soil, and it rises as the water rises.

The author then describes the different means of culture of this plant by slips, and by transplanting it in tufts of roots. The latter method has given the best results. The planting should be done in the month of May, or June, preferably, although if planted in July it will grow, but there is not sufficient time for it to become solidly rooted before the cold weather and the ice come on. The method of planting in quite deep water is described, and the special tool used for forcing the tufts down into the soil is shown in fig. 2 (No. 73). The scirpe (cirpus lacustris) makes in quite deep water a thick vegetation, especially in a peaty soil, less in a sandy soil. On account of the extraordinary flexibility of the stalk, it sustains the strongest attacks of waves or of tempests without being broken or torn up. This is planted very much like the "jonc" (jonquil). The author then describes the osier willow, which is used above the level of the water, as is shown on the sections. He does not consider this an aquatic plant, as the root perishes in deep water, and it is never planted to a depth greater than a half a meter below the ordinary level of the water. The various plants which have been employed in the protection of this canal, and described above, have been very successful, and up to the present time they have withstood the effects of the waves from steamers which have used this canal with a very heavy traffic during construction. This work will be finished in 1900. By that time it is expected there will be a strong, vigorous, green belt of aquatic plants and of willows protecting the artificial dikes, as well as the banks of the canal.

It will be of use to anyone who desires to ascertain fully the details of the materials employed and the methods of their employment to consult the original paper. These details are too lengthy to be given here, except in the above brief résumé.

PAPER BY MR. EICH, OF STETTIN.

This paper relates entirely to the methods employed to protect the channel between Stettin and the Baltic Sea. The width of the channel at the bottom, which is through a Haff very much like the one described in the preceding paper, is 70 to 80 meters (229.65 to 262.46 feet). The slopes are 3 of base to 1 of height, and the final width at the surface of the water will be 230 meters (754.6 feet). The improvement works were commenced in 1895, for the purpose of increasing the depth from 5.70 to 7 meters (18.7 to 22.96 feet). The facts given in the paper were derived from the execution of these works. The natural direction of the current is from the Haff to the Baltic Sea, but the slope in that direction being so very small—1 in 180,000—the north winds often change the course of the current, just as the current is

changed in fluvial rivers which are subjected to the action of the tide, except that in the case in question this change of the current is very irregular; but at times it has very considerable velocity, and has attained 2.40 meters (7.87 feet), and in exceptional cases 4 meters (13.12 feet), per second. These currents find a bed in the Swine, formed of marine sand, very fine and excessively changeable. The great depths, which sometimes reach 20 meters (65.6 feet), and the sudden variations of these depths in pronounced curves, show how easily this sand can be moved by the currents. It will be seen that the banks of a navigation canal cut in earth of so little resistance would have to be consolidated with special care. Not only will the upper part of the slopes need to be protected against waves from passing steamers, but the lower part of the slopes must also be protected against the current, the latter having been done in a simple manner by the aid of platforms or fascines extending from the level of low water to a depth of about 7.50 meters (24.6 feet). (See fig. 1, No. 75.) It was then necessary, in order to protect them against anchors, etc., to deposit upon them quite a large amount of sand from the dredges. This sand enters into the interstices of the fascines. These platforms are about 20 meters (65.6 feet) in length. They are laid side by side and connected. An attempt was made in placing these on the concave bank, which is the one protected, to arrange them at a considerable distance apart, but this was not successful, because the intermediate parts not protected were cut out by the currents. In isolated parts, where the new canal traverses large areas of water, it became necessary to create a new bank. This was done by a suction dredge, which threw out the sand laterally upon the location for the future bank. The upper part of the bank, which is exposed to the action of waves from passing steamers, has been protected in a special manner. The general plan and method of procedure is very much like that described in the previous paper by Mr. Gerhardt, by reeds and rushes. In protecting the canal through the Great Haff it was necessary to build a mole, the character of which is shown in fig. 2 (No. 75), with the exterior slope protected with jonquil and with osier willows in the interior of the mole itself.

PAPER BY MR. W. H. HUNTER, CHIEF ENGINEER MANCHESTER SHIP CANAL.

This paper embraces thirty-five points, which will be briefly referred to. The paper is of great importance, inasmuch as the canal itself is one of the most important in the world, and has a navigation which requires the best protection to the banks.

1. *Scope of the report.*—The subject of bank protection of ordinary

canals has been so fully treated in previous reports of the congresses, this paper confines itself to ship canals exclusively.

2. *Experience on the Manchester Ship Canal.*—This canal was opened to commerce in 1894, and experience gained in reference to wave action and wash produced by passing steamers may be of value in other similar works.

3. This canal was constructed so as to give at the outset a sufficient width to allow two large ocean steamers to pass each other at almost any point of its length of 35 miles.

4. The ruling width is 120 feet at the bottom; the depth of water 26 feet, and the average width at the water level about 200 feet. The average sectional area is therefore rather more than 4,000 square feet.

5. When steamers pass each other, they do so at very low speed. Consequently the wave effect upon the banks is inappreciable.

6. The ratio between the section of the canal and the immersed section of a ship drawing, say, 24½ feet of water is about 4 to 1.

7. Through rock cuttings, where the width at the surface is diminished to about 130 feet, the mean area is about 3,200 square feet, and in that case the ratio is about 3 to 1. This reduction of area has caused a sensible increase in wave height and action.

9. The speed of the steamers by the regulations is 6 geographical miles per hour, although coasting and other steamers of comparatively small size are allowed 8 miles per hour; but it requires constant watchfulness to prevent higher speeds. Coasting steamers sometimes attain in straight reaches speeds varying from 10 to even 13 miles per hour.

10. With the protections of banks employed no injurious effect has been produced upon them by any vessel, large or small, steaming at a rate of 8 miles an hour; but if that rate is exceeded, even by a small vessel, injury follows, and that degree of injury is proportionate to the excess of speed.

11. The canal is excavated generally through riparian valleys; consequently the material was very varied. Sometimes the excavation was almost wholly in beds of red sandstone rock, but the material was of a very uncertain and unreliable nature, harder beds alternating with red marls and with beds of rock of so soft and rotten a character as to be little better than adhesive sands.

12. Wave action upon such banks had a tendency to injure the soft parts of the rock, and these have been restored by brickwork laid in cement.

13. In addition to the rock the canal was sometimes through glacial and post-glacial deposits, bowlder clay, and also through beds of soft wet sand and of marsh loams.

14. The original plan was to protect the slopes with heavy sandstone pitching, except through good solid rock.

15. But this plan was only partly carried out, and only in those locations where artificial embankments were formed to separate the canal from the estuary of the River Mersey, about 14 miles in length. (See sections No. 1 and No. 1 a, No 77.)

16. It was also used where the sides of the canal were soft and there was difficulty in sustaining the slopes during construction. (See section No. 1 b.)

17. Other plans were substituted for this method of pitching; for instance, a belt of light sandstone facing separated by heavy blocks recessed into the bank (see section No. 2). At other places slag from furnaces was used, and in another place mattress work (see section No. 3), like that on the coast of Holland.

18. The heavy sandstone pitching carried up from the bottom of the canal has given an entirely efficient protection to the banks. It has given no trouble and requires practically no expenditure for maintenance.

19. It has, however, disadvantages. The cost is considerable; there is some risk of damage to the steamers, especially when they have twin screws; it is difficult to form passing places or construct wharves.

20. On the other hand, there are disadvantages in the light facing. It is subject to constant disturbance, requires continual expenditure to maintain it, and suffers serious damage when boats run into it.

21. However, it has advantages. It is not expensive and is not so likely to injure the screws of vessels.

22. The mattress work was a failure. It was formed by driving pegs into the slope and interlacing hazel and other rods which were twined around the pegs. It was constructed by workmen brought especially from Holland for the purpose. It was altogether unsuitable for protection of the banks of the large canal.

23. It failed in the following manner: The rods, of whatever material made, rotted in the water, the material washed out from between the pegs, and then the whole work was speedily destroyed. They had to be replaced with stone facing at almost every point.

24. Nearly all experimental materials have been abandoned; for instance, the red sandstone furnace slag and rough red bricks.

25. White limestone of an excellent quality obtained from the quarries near "Great Ormes Head," in North Wales, has been substituted.

26. Excellent results have followed from the use of this limestone.

27. As to its conveyance and cost, it is brought in small coasting vessels of about 200 tons each, loaded at the quarries and discharged at the actual point required on the bank of the canal, the cost being 3s. 9d. ($0.84) per ton. The average thickness is 9 inches and the whole facing is solidly hand packed in place. (See section No. 4.) The limestone is angular, which assists in holding it in place.

28. The foundation for this facing, as the work was done after the water was admitted into the canal, had to be properly prepared.

29. The method adopted was to drive short piles into the bank at distances of from 2 to 3 feet apart, center to center. The heads were connected by longitudinal waling, while in front of and behind the piles rough stonework was formed upon which the facing was constructed. (See section No. 4 a).

30. This method was generally satisfactory, although there is trouble at some points, owing to the washing away of the material below the toe formed by the rough stonework. It is difficult to arrange such work under water.

31. There have been extensive experiments made in reference to wave action as to the extent as well as to the effect of wave action upon the banks of the canal.

32. The details of these experiments, which are very important, are given in the appendix. (See Plate (No. 76).)

33. The author gives certain general conclusions gathered from his experience.

a. In excavation in natural ground the slopes need not be protected with stone or other material the whole depth of the canal.

b. In embankments the entire slope should be protected.

c. Above the water line the slope should be protected against the wash of steamers.

d. Hard angular stone of such size that one man can place it in position is the most effective protection. The author here refers to the fact that white stone is better than dark, as it gives assistance to navigators in the nighttime.

e. There should be a substantial toe or foundation for the stone facing.

f. This should be placed 5 feet below level of the water, this being the level of the plane of deepest erosion.

g. It should be carried sufficiently high above the water to protect against the highest waves from passing steamers.

h. The height is 5 feet.

i. Probably the best method to form a toe for the foundation is to make a berme at the depth of 5 feet below water level.

j. The stone from the berme to the water level should have a slope equal to the angle of repose of the material.

k. Above that point it should have a steeper slope, say 70°, or 1 horizontal in 3 vertical.

34. The general conclusion of the author is that if he were to undertake the construction of any large canal he would provide for such works as the foregoing conclusions indicate as necessary.

35. These conclusions under different materials and under different conditions are shown on plate (No. 77).

Fourth question.—Dredging: Latest high-power dredges; under what conditions used; output; unit prices.

PAPER BY M. L. VAN GANSBERGHE, PRINCIPAL ENGINEER PONTS ET CHAUSSEES, ANTWERP.

CHAPTER I.

SKETCH OF THE WORKS.

NOTE BY THE EDITOR.—This paper relates entirely to dredging in the Scheldt below Antwerp, and is confined to the work at two locations, Krankeloon and the Belgian Sluis.

By reference to Plan I (No. 78), which shows this stretch of the river before and after the dredging operations, it will be seen that at Melsele there is a quite pronounced bend of the river, which, by the current being on the opposite side, produced a bar at the Pass of Fort Philip, and that just below the Pass of Lillo, farther downstream, there was a crossover of the current, making a neutral point and forming a shoal. The amelioration of the channel consisted in dredging away the point at Melsele, as shown by the hatched area, and dredging in the bed of the river at the Pass de Lillo. These obstructions to the navigation compelled vessels to pass from one bank to the other and to conform to a curvature which was very pronounced, and at the lower point it was discovered by dredging that there were high points in the channel, formed of lumps of stone and ferruginous matter hidden in a mass of clay. After dredging to 8 meters (26.24 feet) below low tide the dredging passed from the clay into what was found to be a sandstone formation. These materials were very compact and very difficult to raise. A suction dredge was not successful. Consequently it was necessary to employ a ladder bucket dredge.

Conduct of the works.—The dredging works were begun at Krankeloon in September, 1894, and were carried on continuously up to the end of 1897, except during interruptions in the winter, caused by the movement of ice, and at times by the necessity for repairing the plant. A depth of 6 meters (19.68 feet) below low tide was first dredged and was then carried to 8 meters (26.24 feet).

Place of deposit for the dredged material.—At the beginning this material was thrown out upon lands acquired by the State and placed at the disposal of the contractor. They were located 3.5 kilometers (2.17 miles) above Krankeloon. Material was dredged by ladder bucket dredges and deposited into scows, which were towed to a point in front of the deposit ground, where they were discharged by a suction pump placed on a special boat along the bank of the river. The materials dredged and brought to the point by the suction dredge in its own hull were discharged by a plant upon the boat itself. In both methods the distance from the river bank reached about 500 meters

(1,640 feet), and the depth of material thrown out varied from 2 to 7 meters (6.56 to 22.96 feet). The water thrown out with the excavations behind the dike returned to the river after settlement by a special discharge lock built under the dike. Since 1896 the materials dredged have been discharged into an abandoned pass by means of barges with bottom doors, or by means of a suction dredge in the same manner as above described.

CHAPTER II.

DESCRIPTION OF PLANT.

(See Plate II (No. 79).)

There were 3 dredges employed—3 ladder bucket dredges and 1 suction dredge. Also one called the "Scheldt I," used for discharging upon the bank the materials brought in the scows. For transportation there were 4 towboats and 20 scows.

Ladder bucket dredges.—A complete table is given of the special features of these three dredges, named Giesendam, Elisabeth, and Scheldt III. The sizes are, respectively, as follows: Length, 32 meters (104.98 feet); 40.5 meters (132.87 feet); 45 meters (147.63 feet). Width, 5.8 meters (19.02 feet); 6.5 meters (21.32 feet); 7 meters (22.96 feet). Depth, 2.6 meters (8.53 feet); 3.15 meters (10.33 feet); 3.35 meters (10.98 feet). A description of the boilers and of the materials is given, as well as the hourly consumption of coal and other such features. The capacity of the buckets are, respectively, as follows: 0.35 cubic meter (12.36 cubic feet); 0.45 cubic meter (15.89 cubic feet); 0.6 cubic meter (21.18 cubic feet). The output per hour is, respectively, 160 cubic meters (5,650 cubic feet); 225 cubic meters (7,946 cubic feet); 300 cubic meters (10,594 cubic feet). The Scheldt III (fig. 1 (No. 79)) had a complete installation as a suction dredge, having a pipe of 0.6 meter diameter with a centrifugal pump 1.6 meters (5.25 feet) diameter, actuated by the motor of the bucket ladder. These three ladder bucket dredges worked with their head to the ebb tide. They could work with a head to the flood tide, but it would require such a long time to turn them about that the work was only done during the ebb. They could work about thirteen to fourteen hours a day. The interruptions to the work, due to the changing of the scows, reduced the effective daily excavation to the following figures, respectively, as named above: 1,350 cubic meters (1,765.7 cubic yards); 2,900 cubic meters (3,793 cubic yards); 3,700 cubic meters (4,839 cubic yards). Each dredge was anchored with six anchors, one forward, one aft, and the others on the side. The excavated cut has a width of 50 meters (164 feet), and a thickness generally of 2 meters (6.56 feet), except for the Scheldt III, which was capable of lifting a mass 3 meters (9.84 feet) thick.

Description of Suction Dredge, Scheldt II.

(See figs. 2 and 3 (No. 79).)

The author states that this dredge is of a multiple type, and there is not, according to his information, a similar dredge. It can discharge the material from the hull of a scow placed alongside; it can fill its own reservoir with excavation, which has a capacity of 450 cubic meters (588.58 cubic yards); it can discharge its own load upon the bank or into a scow by different pipes shown in the sketch. It can also discharge its own load by valves in the bottom at g. This dredge has a combined triple-expansion engine with three cylinders of 300 indicated horsepower, and by means of a clutch the screw of the boat can be worked by the same engine. One peculiar arrangement for meeting the great amplitude of the tide, about 7 meters (22.96 feet), is shown in fig. 3 (No. 79), where there are at "m" and "n" spherical joints and a telescopic attachment in the pipe at "l." This dredge is 48 meters (157.48 feet) long, 8.6 meters (28.21 feet) wide, and 3.9 meters (12.79 feet) deep. The diameter of the pump is 1.6 meters (5.25 feet). The wings of the pump, 3 in number, are curved, their surface being the form of a cylinder parallel to the axis of rotation, and of which the directrix is an arc of a circle of 0.8 meter (2.62 feet) radius with a straight part beyond. The suction and discharge pipes are 0.61 meter (2 feet) in diameter. There is a centrifugal pump for the purpose of throwing water into the scows to liquefy the material when it is to be discharged. The boat is provided with electric lights for working at night. It is held by two anchors placed above in such a manner as to prevent lurching back and forth, and can work in the flood as well as in the ebb. The dredge can excavate to a maximum depth of 13 meters (42.65 feet). Its output depends entirely upon the nature of the material. With good material it can fill its tanks in thirty minutes. To empty the boat by suction and discharge upon the bank over a dike, it takes, on the average, about fifty minutes, this depending upon the height and the distance. The daily work covered about eighteen hours, during which time it made ten trips, going a distance of 1.5 kilometers (0.93 mile). When these materials were discharged into the Scheldt it handled about 4,500 cubic meters (5,886 cubic yards) per day. The mean volume was 3,600 cubic meters (4,709 cubic yards) per day. When the distance increased to 4 kilometers (2.48 miles), the number of voyages was reduced to a maximum of six, and the material excavated to 2,700 cubic meters (3,531 cubic yards). The author then describes a suction boat, Scheldt I, fig. 4. This was anchored along the banks at the place of deposit for taking material out of the scows which were brought to it, discharging it over the dike.

Chapter III.

Unit Prices and Results.

The work was let to a contractor at the following prices: Excavation, transportation, 3.5 kilometers (2.17 miles), and deposit in the polder of Borgerweert, 0.65 franc (9 cents cubic yard); excavation, transportation, 1.5 kilometers (0.93 miles), and discharge in the Pass of the Scheldt, 0.27 franc (4 cents cubic yard); excavation and loading into a scow, 0.19 franc (2.4 cents cubic yard); transportation by water per kilometer, 0.02 franc (0.3 mill cubic yard); discharge of the scows in the Scheldt, 0.07 franc (1.1 cents cubic yard); dredging into a scow and putting it into embankment in the polder of Borgerweert, 0.25 franc (3.9 cents cubic yard); in dredging heaps of stone found in the bed there was allowed an extra of, say, 3.5 cents per cubic yard.

The whole amount of the dredging is as follows: Placed in the polder of Borgerweert, 5,454,092 cubic meters (7,133,949 cubic yards); deposited in the Pass of the Scheldt, 1,942,682 cubic meters (2,541,025 cubic yards). The contractor was obliged by his contract to move weekly 30,000 cubic meters (39,238 cubic yards), and the mean amount actually moved was 50,000 cubic meters (65,397 cubic yards) and the maximum, 70,000 cubic meters (91,556 cubic yards).

The various dredges had an output and cost per cubic meter as follows:

Geisendam: Excavating, transporting 10 kilometers (6.21 miles) and discharging into the Scheldt, requiring a tug and five scows, 1,350 cubic meters (1,765 cubic yards) per day, at 0.70 franc (10.4 cents cubic yard).

Elizabeth: Transporting 2.5 kilometers (1.55 miles) and discharging into the Scheldt, employing a tug and three scows, 2,900 cubic meters (3,793 cubic yards) at 0.31 franc (4.8 cents cubic yard).

Scheldt III: Transporting 3.5 kilometers (2.17 miles) and discharging upon the lands of the polder 400 meters (1,312 feet) behind the dike, and employing one tug and five scows and using a suction boat for discharge over the dike, 3,700 cubic meters (4,839 cubic yards), at 0.65 franc (9.6 cents cubic yard).

Scheldt II: The suction dredge excavating, transporting, and discharging upon the polder with a transportation of 4 kilometers (2.48 miles) 2,250 cubic meters (2,943 cubic yards) per day, at 0.65 franc (9.6 cents cubic yard). When discharging into the Scheldt, after the transportation of 1.5 kilometers (0.93 mile), the daily amount of 3,600 cubic meters (4,708 cubic yards), at 0.27 franc (4 cents cubic yard).

The author then gives the actual cost, as near as practicable, the above being contractors' prices, including, of course, his profit. He figures it out as follows:

	Francs.	Dollars.
Suction dredging, cost of dredge	250,000	50,000
Payment of the principal (amortization) in 3 years, with 270 days of work in each, per day	335	67.00
Repairs, per day	75	15.50
Expenses of operation, coal, oil, salaries, insurance, per day	a310	62.00
Total	720	144.50

a About.

When the dredge discharged it load upon the bank, the price would be, according to the above, 4.9 cents per cubic yard. When it discharged into the Scheldt, 3 cents per cubic yard. Of course, the above does not take into account the general expenses of the contractor.

Under what conditions to use the two types of dredges.—The suction dredge is in general use in light, sandy material. It can work in either direction of current; and as it does not require anchors and chains, the boat can easily change its position, and it does not interfere with navigation. When the excavated material is hard, compact, and heavy, bucket dredges should be used.

PAPER BY M. H. DESPREZ, ENGINEER PONTS ET CHAUSSÉES, PARIS.

In the amelioration of the maritime part of tidal rivers dreding has become a feature of capital importance, whether its object is to assist fixed works in forming the bed of the channel or used itself as a basis for improvement. The plant employed ought to be able to handle large volumes of material, and the price ought to be as low as possible, in order that the method may be used. The method has become so important that it has led to organizing special dredging plant and a force by the State itself, rather than to have recourse to contract work as an intermediary.

Dredging comprises two distinct operations—the excavation of the channel and the transport of the material. The first of these operations presents difficulties, especially in the neighborhood of the sea where it has to contend against wave action. The second has its difficulties also, on account of the greater and greater distance which it is necessary to carry the material. It is only rarely that the material can be discharged into the river bed itself, and a means must be found generally to discharge the material upon the banks. The

author then gives the volume of work done on the various rivers of France as follows:

Years.	Adour.		Garonne.		Loire.		Seine.	
	Cubic meters.	Cubic yards.	Cubic meters.	Cubic yards.	Cubic meters.	Cubic yards.	Cubic meters.	Cubic yards.
1895.....	(a)	(a)	994,402	1,300,673	558,755	730,818	299,600	391,866
1896.....	148,444	194,154	812,514	1,075,807	666,080	871,202	b 990,865	c 1,092,243
1897.....	772,879	1,010,885	d 659,000	861,972	945,175	1,236,289	218,009	285,156

a Work was not begun on the Adour until the middle of 1896.
b Tonnes.
c Short tons.
d Exceptional floods suspended the works and diminished the cube of the output on the Garonne.

Ladder bucket dredges and suction dredges are the only kinds employed. The first are adapted particularly to materials the most various—clay, mud, gravel. The second can be satisfactorily employed only in sand mixed with a proportion of mud sufficiently small not to prevent the quick settlement of the material. The excavations have been discharged either directly into the beds of the rivers or into the sea by means of scows with hoppers or by steam hopper barges or from the dredges themselves when they were suction dredges, and by lifting the material and placing it upon the bank by means of elevators or by suction pumps.

I. Ladder Bucket Dredges.

The dredges used on the rivers have dimensions equal to the large marine dredges. They must not only have a large output, but be capable of attacking soil having a great resistance. In order that they may be moved about freely they generally have a double screw. The capacity of the buckets varies according to the nature of the soil to be dredged and the power of the engines. They are generally armed with a cutter easy to replace, as the life of a cutter is always much less than that of the bucket itself. The body of the bucket is in steel, the bottom of cast steel.

The author then describes in considerable detail the various features of these dredges, which it is not necessary to go into at length. His tables are of great value and are given complete:

Dimensions.		Garonne (Dredge No. 4).	Charente (Ville-de-Rochefort).	Loire.
Length	meters	35.00	43.83	32.00
	feet	114.82	143.79	105
Width	meters	8.00	10.00	7.20
	feet	26.25	32.80	23.62
Depth	meters	5.50	3.40	2.50
	feet	18.04	11.15	8.20
Draft	meters	2.25	2.50	1.50
	feet	7.38	8.20	4.92
Displacement	tonnes	700	720	260
	tons	660	708	256

Dimensions.		Garonne (Dredge No. 4).	Charente (Ville-de-Rochefort).	Loire.
Horsepower	chevaux	160	450	90
	horsepower	158	444	88.76
Capacity of buckets	liters	400	750	250
	gallons	105.6	109	66
Number of buckets moving per minute		15	15	16 and 17
Maximum depth of dredging	meters	13.50	10.00	9.00
	feet	44.29	32.80	29.52
Capacity of wells		0	0	0
Output per hour	cubic meters	250	.....	150
	cubic yards	327	.....	196
Speed	knots	0	6	0

Dimensions.		Seine (Ville-de-Rouen).	Le Havre (Andree).	Dieppe (Manche).	Boulogne (Pas-de-Calais).
Length	meters	45.75	55.50	51.20	54.80
	feet	150.09	182.08	168	179.78
Width	meters	10	10.25	9.20	10.10
	feet	32.80	33.62	30.18	33.12
Depth	meters	5.20	4	4.28	4.26
	feet	17.06	13.12	14.03	13.97
Draft	meters	2	2.70	2.65	2.90
	feet	6.56	8.85	8.69	9.51
Displacement	tonnes	645	832	.....	1,384
	tons	635	819	.....	1,362
Horsepower	chevaux	400	500	500	660
	horsepower	394	493	493	650
Capacity of buckets	liters	510	750	350	520
	liters	750	.....	.....	500
	gallons	134.6	198	92.4	137
	gallons	198	.....	.....	132
Number of buckets moving per minute		14	8	16	10–15
Maximum depth of dredging	meters	10.50	12	9.50	12.50
	feet	34.44	39.37	31.17	41.01
Capacity of wells	cubic meters	0	0	320	320
	cubic yards	.....	.....	418	418
Output per hour	cubic meters	400	350	200	300
	cubic yards	523	458	261	392
Speed	knots	6	7.5	7	6.25

The output indicated in the above table is a mean and very variable, according to the nature of the excavations. The maximum output of the dredge Ville-de-Rouen, working in a bank of conglomerate gravel, was 4,064 tons in one day of seventeen hours' work, and an amount very much inferior to the output of which it is capable in free material.

II. Suction Dredges.

These dredges have great advantages over ladder-bucket dredges. They are moved much more easily, they get to work quickly, and they encumber the channel much less. Generally they do the work at much less cost; as the engines have to be of great power the boat can have a considerable speed. They are, therefore, often made as transporters of the material. The marine form which it is easy to give

them allows them to be used in a considerable sea way. In the river they are generally held with one anchor when anchored at all, or they can dredge while moving. The latter method accomplishes the purpose much quicker and can be always used to advantage where the channel to be dredged extends some distance. On the rivers themselves this is not always possible. The author then discusses the question of whether the suction pipe should be extended forward or backward or arranged so as to be placed in either direction. When operating in a stationary position, it is of advantage to make the excavations as deep as possible, but the clogging of the pipe should be avoided. In order to determine whether the pipe is becoming choked there has been placed on one of the dredges an automatic indicator. Formerly it was considered impracticable to dredge when there was a wave of more than 1.20 meters (3.94 feet) in height. The shocks which were produced were likely to injure the suction pipe. On the Adour this danger has been avoided by special inventions, so that the dredge can work in waves 2 meters (6.56 feet) high. These inventions consist, first, in suspending the head of the pipe by means of a suspended Cardan joint, permitting it to adapt itself to any movement of the boat without injury to the joint; second, to place at the lower end of the suction pipe a telescopic arrangement which permits the extreme end to move laterally from about a half meter from the line of the axis of the pipe. It is arranged with Belleville springs. The suction dredge, (in construction,) for the Seine can be used for the dredging itself and the discharge either into scows or upon the banks. The dimensions of the suction dredges working on the three rivers are given in the following table, which also gives the data relating to a certain number of similar dredges in service in the maritime ports:

Dimensions.		Adour (Bayonne).	Loire.	Seine (Seine)	Saint-Nazaire (Bonne-Anse)
Length	meters	53.50	48	43	49
	feet	175.52	157.48	141 07	160.76
Width	meters	8.90	8.60	8	9.50
	feet	29.2	28.21	26 24	31 17
Depth	meters	3.80	3.35	3.60	4.00
	feet	12.46	10.98	11.81	13 12
Draft:					
Light	meters	3	2.20	2	.....
	feet	9.84	7.22	6.56	.....
Loaded	meters	3.50	2.80	.....	3 35
	feet	11.48	9.18	....	10.98
Displacement	tonnes	1,243	870	....	1,165
	tons	1,223	856	.....	1,146
Horsepower	chevaux	450	500	600	400
	horsepower	444	493	592	394
Suction pipes:					
Number		1	1	2	1
Length	meters	18.30	13.50	18.40	17
	feet	60	44.29	60.36	55.77
Diameter	meters	.60	.60	.60	.60
	inches	23.6	23.6	23.6	23.6

Dimensions.		Adour (Bayonne).	Loire.	Seine (Seine).	Seint. Nazaire (Bonne-Anse).
Pump:					
Diameter	meters	1.17 1.89	1.90	1.60	2
	feet	3.83 4.55	6.23	5.25	6.56
Discharge per minute	cubic meters.	76 to 110	105	100	90
	cubic feet	2,684 3,885	3,708	3,531	3,178.3
	cubic meters.	89 to 140	.....	.....	.....
	cubic feet	3,143 4,944	.....	.....	.....
Depth of dredging	meters	12	9	10.50	12.50
	feet	39.37	29.53	34.44	41
Capacity of wells	cubic meters.	356	250	.....	455
	cubic yards.	465.62	327	.....	595.12
Output per hour	cubic meters.	423	200	600	.....
	cubic yards.	553.26	261.6	784.77	.....
Speed	knots	8	8.50	11	7

Dimensions.		Dunkerque.	Calais (Calais I).	Boulogne (Boulogne II).
Length	meters	42	48.60	47.20
	feet	137.8	159.44	160.75
Width	meters	8.80	8.50	9
	feet	27.23	27.88	29.53
Depth	meters	3.40	3.60	3.60
	feet	11.15	11.81	11.81
Draft				
Light	meters	2.50	2.70	2.50
	feet	8.20	8.85	8.20
Loaded	meters	3.50	3.20	3.05
	feet	11.48	10.49	10
Displacement	tonnes	260	232	390
	tons	256	228	384
Horsepower	chevaux	160	210	300
	horsepower	158	207	296
Suction pipes:				
Number		1	1	1
Length	meters	16.10	12	17.20
	feet	52.81	39.37	56.42
Diameter	meters	.50	.60	.38
	inches	19.7	23.6	15
Pump:				
Diameter	meters	1.80	1.80	2.50
	feet	5.90	5.90	8.20
Discharge per minute	meters	50	60	75
	feet	1,765.73	2,118.88	2,648.60
Depth of dredging	meters	11	11	15
	feet	36.09	36.09	49.21
Capacity of wells	cubic meters.	240	270	455
	cubic yards.	313.91	353.15	595.12
Output per hour	cubic meters.	180	210	200
	cubic yards.	235.43	274.67	261.59
Speed	knots	5	6	6

III. Transport and Discharge of Materials.

This is done easily by means of hopper barges or steam hopper barges when there is at command a sufficient area in the river for the discharge of the materials, but these areas are rapidly diminishing, and therefore it is often necessary to raise the material upon the bank, particularly to avoid transporting it a very great distance. This raising upon the bank is done by means of fixed or floating elevators.

With dredges of great power the hopper barges ought also to have large dimensions, in order to reduce the time lost in transportation and to reduce the cost of the work. When the distances are sufficient it is best to substitute, for scows towed by tugs, steam hopper barges.

On the Loire, where the distance of transport reaches 35 kilometers (21.75 miles), sometimes even 55 kilometers (34.17 miles), and where the discharge is made in the open sea, the hopper barges are veritable seagoing boats of large dimensions. The following is an illustration:

Length	meters	40
	feet	131.23
Width	meters	8
	feet	26.25
Depth	meters	3.20
	feet	10.49
Draft:		
Light	meters	2.20
	feet	7.22
Loaded	meters	2.75
	feet	9.02
Displacement	tons	640
	tons	630
Horsepower of engines	chevaux	320
	horsepower	315.6
Capacity of wells	cubic meters	250.3
	cubic yards	327
Speed	knots	7.5

Each dredger is served by three of these steam hopper barges, and also by hopper scows, which need to go only a short distance to discharge. The author then describes the floating elevators which are placed along the bank and take the material from the scows and discharge it upon the land.

IV. Cost of Dredging.

The cost of dredging depends not only upon the nature of the soil, the machinery employed, the distance and method of transport, but upon a large number of conditions varying with the circumstances to such an extent that it is difficult to give this subject a general conclusion. It is only possible to state the results obtained in certain defined conditions and to observe that the cost has decreased in large

measure during the last few years. It is also necessary to remember that it is difficult to compare with any precision the costs given upon various works, for the reason of the difference in conditions, and also because the cost reported is sometimes by weight and sometimes by volume; also because the figures are based sometimes upon the excavation really made and sometimes upon its volume in the wells of the dredges or scows. There can be as much as 20 to 30 and even 45 per cent difference due to these various causes. In the following data the interest on capital of the first cost and the payment of the principal are not considered.

1. DREDGING BY LADDER BUCKET DREDGES.

Dredging on the Garonne.—In 1896 this was done with five ladder bucket dredges of different power and nearly all of the material was placed upon the bank. The mean cost, transported to a mean distance of 4.350 meters (14,271.64 feet) and placed upon the bank, was 0.627 franc (9.25 cents per cubic yard). The analysis of this cost is as follows:

	Cost per cubic yard.	
	Francs.	Cents.
Dredging	0.193	2.85
Transportation	.228	3.36
Placing upon the bank	.176	2.60
Management of the discharge	.030	.44
	0.627	9.25

The cost of dredging proper for each one of the dredges varied between 0.145 franc (2.2 cents) and 0.625 franc (9.4 cents) per cubic yard. These costs include the general expenses of the workshops, the repairs and changes, and the general expense of service. The larger cost given above was in moving gravel under particularly difficult and abnormal conditions.

Dredging on the Loire.—In 1897 the dredging of 943,173 cubic meters (1,233,670 cubic yards) with three ladder bucket dredges cost about half a franc per cubic meter (7.4 cents per cubic yard). The dredging proper was 0.17 franc (2.5 cents) per cubic yard. The transportation and discharge by means of hopper barges going only a short distance was the same, 2½ cents. To discharge upon the bank by means of a floating elevator the cost reached 0.34 franc (5 cents) per cubic yard, the cost being divided between towboats, elevators, and barges. The transport and discharge by means of hopper barges, which transported the material a distance up to 35 kilometers (21¾ miles) reached a cost of 0.63 franc (9.3 cents) per cubic yard.

Dredging on the Seine.—These costs given by the ton, which, according to the different nature of the soil, varied between 1,400 and 2,000

kilograms per cubic meter (2,359 and 3,370 pounds per cubic yard), were as follows:

The cost of handling clayey materials, amounting to 267,090 tons in excavating a petroleum basin, was 0.442 franc (6.6 cents) per cubic yard, the cost being divided as follows:

	Cost per cubic yard.	
	Francs.	Cents.
Dredging	0.14	2.1
Transportation and towing	.17	2.5
Discharge	.132	1.9

The length of transport varied between 3 and 13 kilometers (1.8 and 8 miles). The discharge was made by means of a floating elevator, sending the material by a long spout a distance from the bank of at least 100 meters (328 feet).

2. SUCTION DREDGES.

The cost by suction dredges is very much lower than by ladder-bucket dredges. It varies according to the conditions between 0.12 and 0.30 franc per cubic meter (1.8 cents and 4.5 cents per cubic yard). On the Seine the cost was 0.275 franc (4 cents per cubic yard). This higher cost is on account of being able to work in only one tide. On the Loire the use of suction dredges is still too risky to make a precise cost. However, when the distance of transportation does not exceed 35 kilometers (21¾ miles) the cost has not exceeded 0.30 franc (4.5 cents per cubic yard). On the Adour the cost is much less. In 1897, during which there was removed a volume amounting to 772,879 cubic meters (1,010,925 cubic yards), the mean cost was 0.13 franc (1.9 cents per cubic yard). This figure does not include general expenses of the service—that is to say, the expenses relating to soundings and the general inspection—but it does include maintenance and repairs.

REMARKS.

The author gives the plans of several of the dredges employed, and they are found on Plates I and II (Nos. 80 and 81).

PAPER BY MR. GERMELMANN, AT THE MINISTRY OF PUBLIC WORKS, BERLIN.

Considerable dredging has been done in Germany during the last ten years at the following locations:

1. On the improvements of the lower Weser.
2. Upon the construction of the North Sea and Baltic Canal.

3. Upon the improvement of the channel between Stettin and Swinemunde.

4. Upon the construction of the Königsberg maritime canal, partly by contract, but by far the more important part of the work by the government administration; by contract only when the conditions have been such to make it possible to measure the material removed.

I.—The Improvement of the Lower Weser.

Between the years 1888 and 1898 there have been removed 38,500,000 cubic meters (50,358,000 cubic yards) of earth, the most of which was clayey sand. Of this volume about two millions were dredged by contract, and the remainder by administration of the hydraulic works of Bremen. The materials dredged were placed in the cut-off arms of the river and in the maritime estuary. The plant generally was new.

As a small part only of the dredging product could be placed in deep water, and as most of it required a second handling of the material there were located deposit grounds, where the dredged material was brought by scows and emptied, and then rehandled by special dredges and thrown out over the banks. The work was done principally by bucket-ladder dredges. There were attempts made to use a centrifugal pump dredge, but it did not give good results. It was shown that a mixture of clay and sand could not be easily dredged by this method, for while the sand, even very fine sand, was relatively quick in settling in the compartments, a mixture of clay and sand completely diluted in water was drawn overboard by the water. Pump dredges have, however, been employed advantageously at the points above mentioned where the material was to be rehandled and thrown out upon the bank. The bucket-ladder dredges were of three types, respectively, 150, 200, and 250 cubic meters of output per hour, and which, during the operation, could turn alternately on the anchor forward or backward, accordingly as the dredging was done in the ebb or the flood tide. By these dredges there was cut a channel of uniform width and depth. The author then goes on to describe quite fully the details of these dredges, which, being very similar to those employed elsewhere, do not need to be described. Many of the details are shown on Plan I (No. 82).

The scows employed were built of iron with bottom doors, and of capacities ranging from 40 to 200 cubic meters (52.32 to 261.6 cubic yards). The small scows were towed in trains; the large ones were steam hopper barges moving by their own propulsion. On the lower part of the Weser, where the river has a more pronounced maritime character, and where the material to be dredged is sand, quite clean, there was used a suction dredge, the hull of which was a seagoing vessel, and was capable of holding 740 cubic meters (968 cubic yards) of dredged material. This boat had a length of 60 meters (196.85 feet), a width

of 10 meters (32.80 feet), and a depth of 5.25 meters (17.22 feet). The suction pipe was placed on the starboard side and inclined forward. The centrifugal pump was 2.10 meters (6.89 feet) in diameter, making 120 turns in a minute. It would fill the compartments working in sand in 40 minutes. The price, comprising various expenses, interest, and amortization, was 12 to 15 pfennigs per cubic meter (2.1 to 2.2 cents per cubic yard). This work was done by administration. The output of other dredges with the dimensions and the costs of the plant, as well as the price of dredging, is shown in an annexed table. The cost of dredging by ladder-bucket dredges averaged 2.4 cents per cubic yard. The cost by suction dredge, including a rehandling and discharging over the bank, was 7 cents a cubic yard.

II. North Sea and Baltic Canal.

It is unnecessary to go into the details given by the author, as the particulars of this work are so fully described in the published history. The total amount moved in the entire work was 82,200,000 cubic meters (107,500,000 cubic yards), and the mean price was 0.87 mark per cubic meter), (15.9 cents per cubic yard). This cost, however, included all of the various expenses connected with the construction of dikes and of artificial banks through the marshes and marshy lands. The actual cost when the work was done by administration was 75 pfennigs per cubic meter (13¾ cents per cubic yard.) The larger part of the material was excavated in the dry by means of land excavators, the material being hauled some distance by rail to suitable places of deposit.

III. Improvement of the Navigation Route Between Stettin and Swinemunde.

To make a uniform depth of 7 meters (22.97 feet) for this route it was necessary to move 12,000,000 cubic meters (15,500,000 cubic yards). This was done in 1893 to 1897, material being largely sand and clayey mud. The work was mostly done by administration and not by contract. In addition to a large number of small dredges, among which were two suction dredges and a ladder-bucket dredge, with a discharge installation, there were three ladder-bucket dredges newly built and of considerable size. The work was done during the summer months from May to October. During the unfavorable months of April and November the dredges were withdrawn from the Haff to work in locations better protected. The dredges were not supplied with their own motive power. Most of the material was discharged by means of scows in the Haff and in the Baltic Sea. These scows had a capacity of 200 cubic meters (261 cubic yards). There is an annexed table, which gives in details the result of the dredging.

The cost by ladder-bucket dredges with steam-hopper barges was 0.26 mark per cubic meter (4.7 cents per cubic yard). There were no suction dredges.

IV. Königsberg Maritime Canal.

This canal required the removal of about 9,000,000 cubic meters (nearly 12,000,000 cubic yards). The work has already been described in a previous paper upon the protection of canal banks.

It was necessary to build a dike along the bank of the canal in which dredges were used of the ladder-bucket type and provided with a discharge apparatus for discharging over the bank. Where it was necessary to work in pure clay, which was very hard, there was provided a special cutter. An annexed table is given which gives all the information necessary in regard to this work. The cost, comprising transportation to the deposit grounds, but not comprising interest and amortization, averaged 0.24 mark per cubic meter (4.4 cents per cubic yard).

The author gives conclusions from experience acquired in Germany.

1. Dredging which is done in open water exposed to wind and currents is most advantageously performed by direct administration and not by contract.

2. Dredging of which the amount can be exactly fixed and before or during execution is frequently performed more economically by contractors, especially when the plant necessary for the dredging would have to be acquired specially by the administration of the works.

3. Suction dredges can not be employed with an assurance of success, except in light soil, sand, soft marshy earth, and clayey earth which is not hard.

4. Dredging by ladder buckets can be done with certain success in almost every kind of material, even up to quite hard stone.

5. In reference to the transportation of dredged material, there is often used with success, when the deposit ground is in the vicinity, installations of discharge through a closed pipe, partly floating and partly fixed on the land.

6. When the deposit ground is not in the vicinity of the dredging a suction dredge may be used to advantage. Experience has shown that steam-hopper barges of a capacity of 200 cubic meters (261 cubic yards) are of the proper size.

7. When the material can not be disposed of laterally or discharged under water the construction of special ports of discharge is recommended, especially when there are large areas at disposal.

8. At places where the barges can not conveniently work with the dredger there can often be obtained good results by suction dredges.

PAPER BY W. H. WHEELER, OF ENGLAND.

The successful application of suction dredging in suitable materials and the small cost have made it possible to deepen and improve tidal channels, while formerly, with the old kinds of machines, it was impracticable.

The author states certain principles, as follows:

First. That if channels in sandy estuaries are so deepened as to allow a new direction of the currents of the flood and ebb tide the depth is likely to be maintained.

Second. The chief cause of shoaling on the bars at the mouth of tidal rivers is the material drifted on the coast by the action of the tides and wind.

Third. But that the regular and continuous movement of this littoral drift does not extend often below the line of low water.

Fourth. The action of the wind and waves in storms in moving the sand, of which the sea bed is composed, extends only to a limited depth, and its energy decreases rapidly as the depth of water increases.

Fifth. That in a deep channel, where there is a large volume of tidal water oscillating backward and forward, the strength of the current is sufficient to remove any material carried into the channel during storms.

The author believes, therefore, that if due consideration be given to the direction of the tidal currents, the entrance channels to tidal rivers or harbors in sandy estuaries will maintain themselves without the aid of piers or training walls, also that this increased depth can be obtained at a reasonable cost and much less expense than by building jetties or walls. The author instances quite a number of places where the channels have been maintained without permanent works. He gives one special reason for the maintenance of the channel, when deepened by dredging, and that is that a larger volume of tidal water moves backward and forward in one channel, being concentrated within a limited width.

The author then gives successful examples where permanent deep water channels have been made by dredging, and have been maintained.

1. *The ship channel through the bay of New York.*—He gives details of the method, the quantities removed, and the cost.

[Query by the editor: Has not this channel, in the course of a few years, shoaled considerably, making it necessary to dredge again?]

2. *The bar of the Mersey.*—The entrance channel lies between two wide sand banks, which are dry at low water of spring tides. They extend out into Liverpool Bay for a distance of 9 miles. The sands at the upper end of the bay, which are uncovered at low water, extend over

an area of about 70 square miles. Formerly there was only about 11 feet at low water of spring tides, a distance of nearly one-third of a mile. The range of spring tides on the bar is about 30 feet. On account of the deep draft of the American liners it was very inconvenient passing over this bar. The harbor board decided, after several years of discussion, to attempt dredging instead of permanent works. The first dredgers were of comparatively small capacity, but they worked so satisfactorily that a larger one was designed—in fact, the largest dredger at that time existing in the world. It was called the Brancker; its cost was £65,000 ($325,000). It is a twin-screw hopper dredger of 2,560 tons gross register, 320 feet long, 46 feet 10 inches wide, and 20 feet 6 inches deep, with a load draft of 16 feet 4 inches, its speed being 10 knots per hour.

There were 8 hoppers, with a total capacity of 3,000 tons (about 2,000 cubic yards). There are 2 centrifugal pumps. The suction and delivery pipes are 36 inches in diameter. The boat can dredge to a depth of 45 feet. The suction pipes pass down through a well in the center of the vessel. The cost of dredging, including the transportation to deep water, is 1.12 d. per cubic yard (2.24 cents).

3. *The Stroombank.*—The outer harbor of Ostend consists of a long narrow channel through a vast mass of sand banks, which cover all this part of the ocean bed. The depth of the channel varies from 4½ to 5½ fathoms. This harbor is separated from the outer roadstead or main deep-water channel by the Stroombank, which runs parallel with the coast and has a depth of only 10 feet. The rise of the spring tide is 17 feet. This shoal was very obstructive to navigation between England and Belgium. The Belgian Government, therefore, decided to dredge a channel across the bank, so as to have 16½ feet at low water of spring tides. The total amount of material removed was about 1,000,000 cubic yards. The distance to transport the material was about 2½ miles. The work was very expensive, as the dredgers could only work about one-half of the time on account of the stormy weather and repairs. These were suction dredgers of large capacity, capable of removing and depositing about 4,700 cubic yards in a day. There were two contracts. In the first contract the price was about 11 cents per cubic yard and in the second about 7⅛ cents.

4. *The Charpentier Bar of the Loire.*—This is in the Bay of Biscay and in the approach channel to St. Nazaire. The depth over the bar was about 13 feet, the bar being about 1¾ miles wide. The spring tides were about 17 feet. The bar is not composed of the alluvial matter brought down by the river, but of waste matters from the neighboring cliffs. The material is largely composed of large grains of quartz.

After an experiment in hydraulic dredging to ascertain the practicability of the method a contract was entered into to remove 1,308,000

cubic yards, to secure a depth of 16½ feet at low water of spring tides. Four suction hopper dredgers were used. The distance to the discharging ground was 3 miles. It was a very troublesome place to work on account of storms. The cost of wages, coal, repairs, and incidental expenses averaged about 4 cents per cubic yard.

5. *The Port Natal harbor entrance, South Africa.*—The bar at this place had a navigable depth of not over 6 feet at low water and 12 feet at high-water spring tides. The principal dredger used was the *Octopus*, built by Messrs. Symons & Co., of Renfrew, Scotland. The hoppers have a total capacity of 1,300 tons. It has 2 sand pumps, each of 33-inch suction pipes. When this dredger began work, in February, 1896, there was only 5 feet of water over the bar. The draft of the *Octopus* light being 18 feet, she was at first started pumping and discharging the sand over the side, and in about fifteen hours had cut a passage through the bar. In four days' work the secured a navigable channel, with a depth of 13 feet.

Recent reports show that the result of the system of sand-pump dredging, now systematically carried out, has given very satisfactory results, and that a depth of 18 feet is maintained in the channel, and that shoaling does not now take place, the channel, even after heavy gales, having been found to maintain its depth, and that the bar, instead of re-forming, as was formerly the case under similar circumstances, has practically disappeared.

PAPER BY M. J. MASSALSKI, OF HOLLAND.

The author gives three principal facts to guide in the choice of a dredger—the nature of the material to be dredged, the situation, and the location of the place of discharging the material. He then divides the subject into river dredgers and marine dredgers and gives the various kinds of dredgers generally in use; that is, ladder bucket dredgers and suction dredgers discharging into their own hoppers, or into barges, or into steam-hopper barges, or discharging directly upon the land, or discharging into barges and the material then taken from the barges and discharged upon the land. He does not propose to go into the details of construction, but only to note some improvements that have been adopted recently.

1. *Hulls.*—(a) The adoption of two screws at the stern; (b) the improvement in the appliance for the quick discharge of materials from the hoppers.

2. *The windlasses or capstans*, in which there has been great improvement.

3. *The suspension of the ladder or suction pipe* by the adoption of steel cables in place of chains.

4. *The rollers on the top and bottom of the ladders in the case of ladder bucket dredgers.*—The author goes into a considerable discussion to show that the rollers at the bottom should be of large diameter in order that the buckets may have a sweep with a longer radius and so have more power, and consequently do their work of cutting easier.

5. *Links, bolts, and rings.*—The substitution of manganese steel for forged steel, and the same for other working parts of the dredger.

6. *Pumps for handling the dredged materials.*—The author gives details of improvements which need not be discussed here. He refers particularly to the monometer placed upon the suction pipe for noting the pressure and so avoiding the choking of the pipe.

7. *The discharge pipes.*—The adoption of leather elbows of a length equal to double the diameter of the pipe and covered with an armature of steel wire is very advantageous.

The author then gives the different conditions under which different kinds of dredgers should be employed; that is, ladder bucket, dredgers or suction dredgers. Only one point needs to be referred to, and that is the difficulty of handling very light material by means of the hoppers. This material will not settle with sufficient rapidity to make it possible to do the work satisfactorily. Such materials, if possible, should either be removed by a ladder bucket dredger or should be discharged immediately upon the land at the side of the channel.

Ladder-bucket dredgers discharging on shore.—Ladder-bucket dredgers work in all kinds of material, and although the cost of the work is considerably greater, yet the use of such a plan is necessary on a great many works. Sometimes the cost can be lessened when there can be added to the dredger a pipe or spout for transporting the excavated material. Such is the case when this kind of a dredger is used for the maintenance or enlargement of a canal where it is necessary to make a uniform bottom in depth, and where it is possible to dispose of the material on the banks. The author shows in Plan I (No. 84) an example of a dredger which worked in very hard material, described by Mr. M. Bezault, French engineer, in his description of the port of Sfax. Two ladder-bucket dredgers were employed in cutting the channel in the outside bar. Each of the dredgers is arranged so that it can discharge the material either into barges alongside or directly upon the bank by means of a centrifugal pump capable of moving the excavated materials, by means of a conduit 350 meters (1,148.29 feet) long, with 2 meters (6.56 feet) of elevation above the level of the water. There are upon the dredger all the latest appliances in the way of electric lights, with a special pump throwing a jet of water into the hoppers for facilitating the discharge of the dredged products. The centrifugal pump and the floating conduit are of special construction. The diameter of the pump is 1.20 meters (3.92 feet); interior diameter of the conduit is 0.38 meter (1.25 feet). The character of the material

to be dredged was very difficult. At first it was sandy mud and, in that material the dredgers could get results, but there was encountered a bed of conglomerate, reaching a thickness of 0.70 meter (2.29 feet), then a bed of yellow clay, very compact, and several meters in thickness. The thickness of the cutting in this material was 0.30 meter (0.98 foot). In spite of all these difficulties, and others, the dredgers raised 1,220,000 cubic meters (1,595,000 cubic yards). The cost of the entire work, per cubic meter was 0.58 franc (9 cents per cubic yard). Considering the interest on the capital and sinking fund for the payment of the principal, the cost was 0.74 franc (15 cents). The depth of dredging was 9 meters (29.52 feet), and the material was all placed a distance of 350 meters (1,148.29 feet, from the canal, and was raised 2 meters (6.56 feet).

Dredger discharging materials from barges and sending it ashore.—When it is not possible to discharge the material directly upon the shore from the place of excavation the bucket dredger empties its material into barges. If it is too long a distance to tow these barges to the sea an elevating dredge, worked by a centrifugal pump, is often used to take the material from the barges, which are brought alongside of it, and discharge it behind the dike built along the shore. This was done at the anchorage of Port Said. The material was so soft and light and so nearly liquid in its original form, that it could not be handled by a suction pump discharging into its own hoppers, consequently, a bucket dredger was employed, discharging this mud into barges, when the latter were towed only a short distance to the banks and there, by means of a pump, the contents were thrown out upon the land through pipes.

The author gives an instance of the utility of a pump dredger in floating the *Victorious*, the English war ship which got aground in the canal at Port Said. An attempt was made by a large number of towboats to move the vessel, but without success, but the pump dredgers soon loosened the material around it so that it could be floated.

The author then gives a brief description of a marine ladder-bucket dredger, which was used at Koenigsberg, for the purpose of discharging the material upon the shore. (See Plan II, No. 85.) The distance to which the material was discharged was 500 meters (1,640 feet); the pipe was one-half meter diameter.

Sand-pump hopper dredgers.—The author describes a method used by M. Churruca, director of the port of Bilbao, Spain, in which a ladder-bucket dredger and a pump dredger were used together. The cost of the work for five years was, upon the average, about as follows: Sixteen cents per cubic meter (12 cents per cubic yard) for the bucket dredgers and 5 cents per cubic meter (4 cents per cubic yard) for the pump dredgers. The material dredged by the bucket dredgers was carried in hopper barges a distance of 34 kilometers (21 miles), and

that dredged by the pump dredger 18 kilometers (11 miles). Another instance is given where the cost by a pump dredger was 3½ cents per cubic yard.

Large, self-propelling suction dredger.—The problem of retaining in the wells of a suction dredger the soft mud is far from being solved, but a great advance has been made by employing dredgers which have wells of very large size, so that the solid matters pumped up can settle over a large surface. (See Plan III, No. 86.) The author describes briefly a dredger of this kind that is used at the bar of Huelva, Spain. This dredger has wells of 500 cubic meters (655 cubic yards) capacity, and it is able to make five trips per day a distance of 16 kilometers (10 miles); it can dredge to a depth of 12 meters (39.36 feet).

A self-propelling dredger that can take up and discharge the contents of its own wells upon the adjacent banks. It was invented by M. Louis Coiseau. A dredger with ladder buckets and also a sand pump, self-propelling and discharging upon the banks or in the sea.

For the maintenance of the ports on the Baltic Sea, where the dredging conditions are very different in different ports, a dredger of high power has been built to satisfy all exigencies. (See Plan IV (No. 87).) This marine dredger has an endless chain of buckets, and also an installation for pumping, so that it can fill its wells and carry the excavated material to the sea, or discharge upon the land by a conduit. The capacity of the wells is 400 cubic meters (524 cubic yards). The draft of the water, when the boat is loaded, is 3.70 meters (12.13 feet). The depth to which it can dredge below the line of flotation is 10 meters (32.80 feet). The output, with the chain of buckets in hard sand or clay, is 300 cubic meters (393 cubic yards) per hour; by the sand pump, 400 cubic meters (524 cubic yards). It has two triple-expansion engines, working two screws—when these same engines can work—one the chain of buckets and the other the suction pump.

A marine sand-pump dredger, emptying scows and discharging upon the land. This is used on the Lower Seine, where large quantities of sand are in constant movement. The administration of Ponts et Chaussées, of Rouen, have recently put into use an appliance of great power, illustrated in Plan V (No. 88); it has a speed of 11 knots. It dredges to a depth of 10.50 meters (34.44 feet). It can load a scow of 100 cubic meters (131 cubic yards) capacity in ten minutes; it can empty a scow of the same dimensions in fifteen minutes. It can act as a towboat, as it has two screws. It can dredge the material from the bottom and load into scows, or it can easily discharge from the scows by a conduit or pipe a distance of 500 meters (1,640 feet), and a height of 6 meters (19.68 feet), this height being at the extremity of the pipe. It has two independent suction pipes placed on each side of the boat, so that both may be operated at a time, if necessary.

Another powerful pump throws a strong jet of clear water into the scow in order to loosen the material.

All of the dredgers above described are provided with all modern equipments, in the way of steam windlass, steam stearing gear, electricity, water ballast, and other convenient arrangements.

PAPER BY SMULDERS & CO., OF ROTTERDAM.

This paper describes the methods of excavation in dry land and under water, but the latter feature only is treated in this résumé.

The authors divide the subject of "dredgers" into "dredgers with buckets" and "dredgers by suction," and the first method into three series: (1) Loading into scows alongside; (2) discharging the materials by means of floating pipes or by long spouts; (3) seagoing dredgers, carrying material in their own hoppers and discharging it at a distance. The authors then describe dredgers of the different series which they have themselves constructed.

1. One for the marine department of the Imperial Russian Government. (See Plan II, No. 89.) This seagoing dredger has a central ladder and can excavate its own channel through the bars; length of hull, 50 meters (164 feet); width, 10 meters (32.80 feet); depth, 4 meters (13.12 feet). It is provided with two compound condensing engines of 800 horsepower. The buckets have a capacity of 600 liters (158 gallons). The theoretical output per hour is 500 cubic meters (655 cubic yards) when dredging to a depth of 11 meters (36.08 feet) under the water. These dredgers can work by means of a dredging chain or by their own propulsion, which is made by two screws. The speed of the boat is 15 kilometers (9 miles) per hour. The total cost was about 600,000 francs ($120,000).

2. The dredger of the second series, built for the Imperial Russian Government. (See Plan III, No. 90.) This is a seagoing dredger with a central ladder, and can cut its own way through the bars; length of hull 46 meters (150.88 feet), width 8.3 meters (27.22 feet), depth 3.25 meters (10.66 feet). It is provided with three compound condensing engines with 200 horsepower each. The capacity of the buckets is 425 liters (112 gallons), and the theoretical output per hour is 450 cubic meters (589.50 cubic yards), dredging in 8 meters (26.24 feet) of water. These dredgers have two discharge pumps by which the materials dredged can be carried a distance of 500 meters (1,640 feet) at an elevation of 2.50 meters (8.20 feet) above the water surface. The conduit for the discharge is made of floating pipes coupled by flexible joints. Materials dredged can also be discharged upon the land from an elevation of 6 meters (19.68 feet) by means of a long spout, to a distance of 50 meters (164 feet) from the hole. This spout is

suspended by means of a derrick and by cables of galvanized wire. The cost of this dredger, everything included, is about 500,000 francs ($100,000).

3. The dredger of the third series, built for Bulgaria. Length of hull 42 meters (137.76 feet), width 8.3 meters (27.22 feet), depth 3.7 meters (12.13 feet), capacity of wells 500 t. The engines are compound condensing, of 250 horsepower. The excavation is made by buckets of a capacity of 380 liters (100 gallons), giving a theoretical output per hour of 360.8 cubic meters (470.8 cubic yards), dredging in 10 meters (32.80 feet) of water. This dredger can work by dredging machines or by its own power, and can carry dredged material to the sea in its own wells. Its speed is about 12 kilometers (7.45 miles) per hour. The cost was about 350,000 francs ($70,000).

2. *Suction dredgers.*—See Plan IV (No. 91). A recent dredger of this system constructed by the authors has the following dimensions. A seagoing dredger with a length of 70 meters (229.60 feet), a width of 12 meters (39.36 feet), a depth of 6 meters (19.68 feet), capacity of the wells 1,500 t.; operated by two compound condensing engines of 800 I. H. P. Its excavation is done by a centrifugal pump actuated directly by engines of about 130 revolutions per minute. In dredging 13 meters (42.64 feet) below the water, the wells are filled in thirty minutes. In sailing to the discharge ground in the sea the boat has a speed of about 15 kilometers (9 miles). The cost is about 700,000 francs ($140,000).

The authors then describe the methods of transportation of materials by means of scows, which they divide into two types—those with movable bottoms and those with fixed bottoms. The authors also describe the methods of taking the materials from scows by means of elevators, all of which has already been described in previous papers. The dredgers built by this firm are generally provided with an electric installation.

PAPER BY V. E. DE TIMONOFF ON SUCTION DREDGERS.

This paper is an important and valuable résumé of the history of the suction dredgers in various parts of the world.

The table of contents is as follows:

I. Introduction.
II. Characteristic Features of Suction Dredgers.
III. Historical Summary of Suction Dredgers.
IV. Suction Dredgers in Russia.
V. Conclusion.

I. INTRODUCTION.

Ten years ago the author of this paper had begun the movement in favor of suction dredgers, but it met with numerous obstacles, but it has come out victorious over them all, and the result has been

a rapid diminution in the cost of dredging. This diminution of cost has resulted not only from the direct use of suction dredgers, but by an improved installation of bucket dredgers, as it was necessary for the latter to be improved in order to compete with the superior suction dredgers. The author instances the entrance channel of the Port of Libau, where the cost in fine sand was reduced two-thirds. He mentions another case at St. Petersburg, where, in 1892, a contract was let at the rate of 8 rubles 60 kopeks per sagene cube, for easily moved sand. In 1898, in a new project for that port, a similar contract was let for similar work for 2 rubles 50 kopeks, the dredgers being, in both instances, bucket dredgers.

On account of the contest between the two methods of dredging, the author was led to examine and analyze the facts existing, not only in Europe, but in America and other parts of the world. The results of this long investigation were published in a series of brochures, mostly in Russian, forming an extensive monograph on the subject of suction dredgers and their applications. The present paper is a very succinct résumé of a part of this more extensive work. The author does not consider that suction dredgers should be used to the exclusion of other systems, as he believes there are conditions under which other systems can be effectively employed.

II. CHARACTERISTIC FEATURES OF SUCTION DREDGERS.

They can be characterized by the following definitions:

1. They can excavate all semifluid matters; earth naturally friable, such as sand, gravel, and small stones; earth that is susceptible, with the use of water, of being separated artificially and made into a mixture which can be moved; vegetable, clay, and soft marl materials.

2. Suction dredgers transport materials excavated and discharge them by means of conduits by the aid of the very pump which produced the excavation. The deposit of materials can be made either in the hold of the dredger itself, or into scows, or into the water, or upon the bank, and the distance of transportation can exceed 1 kilometer.

3. Suction dredgers occupy only a small space during their work, on account of the necessity of using only a few anchorage chains.

4. Suction dredgers can excavate soils which do not require any artificial separation, and in waves which would make the use of bucket dredgers impossible. They have been used under such conditions in the entrance channels of ports on sandy coasts, such as Dunkirk, Boulogne, Calais, Ostend, Libau, etc.

5. The seagoing suction dredgers, by a special system of doors in the wells, can discharge their contents into a sea disturbed by waves where it would be impossible to handle scows. The dredgers at the mouth of the Mersey furnish a striking example of this kind.

6. Suction dredgers can produce an output which greatly exceeds that of the most desirable bucket dredgers, and where the latter could not work even under the most favorable circumstances. The author cites the example of the Brancker at the Mersey, which has an average output of 2,500 cubic meters (3,270 cubic yards) per hour, and that of the Beta on the Mississippi, which reaches 6,000 cubic meters (7,848 cubic yards) per hour.

7. Suction dredgers, even under unfavorable conditions, work with greater economy than bucket dredgers in favorable conditions.

8. Suction dredgers are often important means for saving vessels that have been grounded in the sea or on the coast.

9. In the sandy bottoms of rivers suction dredgers, with an expense of time and money relatively small, can maintain a navigable depth which can not be assured by the bucket dredgers, even with a considerable expense of time and money.

The first seven definitions above mentioned were made in 1894. Since that time a study of the work of suction dredgers permits the author to add the last two, and he then gives illustrations where vessels that had been grounded were saved by means of suction dredgers.

III. HISTORICAL SUMMARY OF SUCTION DREDGERS WHICH EMBRACES, GENERALLY, THE FOLLOWING:

The invention of the suction dredger by the Americans, Germans, and French, the progress accomplished by the American constructors, and the rôle played by the suction dredger and its application by the engineers of various countries.

The details of this historical summary, which covers 5 printed pages, it is unnecessary to go into, and which would be a valuable reference in case of further investigation.

IV. SUCTION DREDGERS IN RUSSIA.

The suction dredge did not appear in Russia until 1874–1876, when a company was formed to exploit the patent of M. Bazin. This company did considerable work, particularly in cutting the maritime canal at the mouth of the Dneiper, the work costing about 1,000,000 francs ($200,000). This company, however, in 1880, became involved and had to go into liquidation. The nonsuccess was largely due to the small size of the dredgers, rather than to their principle, but this nonsuccess produced a reaction in Russia against suction dredgers, which greatly delayed their further use, and prejudice against them has hardly disappeared at the present time in spite of the incontestable facts furnished by the use of modern suction dredgers in all countries and even in Russia.

The first modern dredger was ordered by the minister of ways and

communications, in 1888, for the port of Libau, which had in front of it an immense bar of sand exposed to all winds, where the maintenance of the channel by bucket dredgers was difficult and expensive. The author was called to direct these works and applied suction dredgers, reducing the cost about one-third in the first instance over the cost by bucket dredgers. From his experience he decided that the cost should not exceed 4 cents per cubic yard, and 2½ cents per cubic yard upon the bar of Vindau. This reduction in the cost produced a veritable revolution in the progress of Russian public works; still the Government was very slow to adopt suction dredgers.

In 1894 a Government congress was held for the purpose of deciding upon this question of the method of dredging. The conclusions were in favor of the suction dredgers, the decision being based largely upon the report of the author. This decision was to the effect that suction dredgers could produce considerable economy, and that their employment could be recommended exclusively for all homogeneous and easily moved earth, such as mud, sand, turf, and several kinds of soft clay, even where the latter material required the use of certain special appliances. The congress also decided that bucket dredgers should also be supplied with suction apparatus. This decision led to the construction of many such dredgers, not only for rivers, but for maritime purposes, particularly the large-sized suction dredger for the port of Archangel, with an output of more than 600 cubic meters (785 cubic yards) per hour.

What has led, however, to the most remarkable development of the suction dredger in Russia has been the decision by Prince Hilkoff, minister of ways and communications, following a voyage of examinations to the United States of America, which led him to give an order for a suction dredger for the river Volga of very large capacity. The specifications for this dredger required that it should work in depths of water from zero to 14 feet. Its output during operation in a bed of sand of 3½ feet thickness should not be less than 3,000 cubic meters (3,930 cubic yards) per hour, and in a bed a thickness of less than 2½ feet, it should not be less than 1,500 cubic meters (1,965 cubic yards). This great dredger was being built at the time of the session of the congress in Seraing, at the works of John Cockerill, according to the plans of Mr. L. W. Bates, of the United States.

The author gives two important tables for the cost of dredging. The first gives the price paid in Russia to the contractors working with bucket dredgers; these prices vary from 4 to 8.70 paper roubles per sagene cube, or 1 franc to 2.20 francs per cubic meter (15 to 33 cents per cubic yard). The second table comprises the price of dredging in different countries for the years 1880 to 1890, varying between 0.11 franc and 0.43 franc per cubic meter (1.6 to 6.3 cents per cubic yard), being about one-tenth to one-fifth of the price by bucket dredgers.

V. CONCLUSION.

Suction dredgers furnish, in soils which permit their employment, the most economical means of excavation and of transport of materials.

PAPER BY LINDON W. BATES, OF THE UNITED STATES.

This paper covers a great deal of ground, not only describing high-powered dredgers designed and built by the author, but goes quite extensively into the subject of the relations between dredgers and navigation, both sea and inland.

The contents of the three chapters are as follows:

1. Evolution of modern hydraulic dredging and the present types of dredgers in Europe and America.
2. A description of certain high-powered dredgers built and designed by the author.
3. Application of the system.

The following plates, though not comprising the entire set shown by the author, will be referred to in the descriptions. Plate 1 (No. 92), Chicago drainage canal dredger No. 2; plate 2 (No. 93), United States dredger *Beta* and pontoons; plate 3 (No. 94), Russian Government dredger *Volga*; plate 4 (No. 95), Russian Government dredger *Nicholaev;* plate 6 (No. 96), electro hydraulic dredgers.

Chapter I.—The evolution of modern hydraulic dredging: (*a*) Rough-water types and characteristics; and under this subject various pioneer dredgers are described. (*b*) Early smooth-water types, in which fourteen different early dredgers of that kind are described. The author then gives the evolution of the means of making the suction feed properly, and describes the principal forms of cutters and the mountings of the same, and of suction-pipe mountings, describing also the various forms of centrifugal pumps, anchors, and dredging chains, discharge pipes, pontoons, and joints, the distribution methods, the movements of the dredgers, etc.

Chapter II takes up high-powered dredgers: (1) Single bucket, clam shell, and endless chain; (2) hydraulic dredgers, *Beta Volga*, and *Nicholaev;* (3) certain dredgers designed by the author of 1,500 and 3,000 horsepower.

Chapter III, which takes up the application of the system, is described by a plate showing many places in the world where dredging by hydraulic dredgers can be successfully applied, does not need to be elaborated.

No doubt the reader will obtain all the necessary information in reference to the various subjects treated in this paper by an examination of the plates above described.

CHAPTER V.

FOURTH SECTION—SEAPORTS.

First question.—Warehouses and sheds; adequacy; size; method of construction; means of access.

PAPER BY F. ANDREAS MEYER, CHIEF ENGINEER OF HAMBURG.

The traffic in a maritime port comprises the deposit of a more or less large amount of merchandise. For that which can not be deposited in the open air there have been provided, since many centuries, warehouses or places of storage where merchandise can be placed before it is shipped and after its arrival. These places permit, in the first place, the storing of merchandise, as well as to clean, bale, sort, and work it over.

Formerly, when sailing vessels were largely used and the tonnage was not great, and only carried merchandise for one special consignee, warehouses were built directly on deep water, and it was generally necessary that this should be on a navigable arm in connection with the port. This was the case at Hamburg. The warehouses were formerly all through the city connected by canals which connected with the port. The merchandise was transported between them on small barges of from 20 to 25 tons. The time required in those days for loading or unloading a vessel was often weeks and even months. On account of the development of steam navigation toward the middle of the present century the situation became greatly modified. A steamer rarely brought merchandise for one single consignee, except in the case of minerals and coal. Merchandise was therefore assorted either on board or after it was unloaded, and this often required different storage places.

The capital invested in the construction of steamships and the great expense connected with their operation requires great rapidity in the handling of the merchandise so as to increase the number of voyages. For this reason there has been now, for some years, quay walls built in deep water where steamers can lie alongside, and cranes of various kinds have been placed which can handle goods from 10 to 12 meters (32.80 to 39.36 feet) from the edge of the quay wall. The transit sheds thus established are connected with the city and with the rail-

road freight depots by wagonway and by railway, as well as by navigable channels, where it is possible, in order that the merchandise may reach its destination as soon as possible; consequently the transit sheds are only an intermediary between the ship and the warehouse.

The movement of merchandise between the ship and the quay and the railroad and the quay constantly increases in its proportions; nevertheless, the amount of merchandise to be warehoused also increases, and therefore it is necessary to increase these installations. This happened at several cities, such as Hamburg, Bremen, Trieste, Copenhagen, and Stettin, all of which are free ports which have for their object, while safeguarding the customs duties, to give to commerce greater freedom of movement. At Havre the free port was established a long time ago. The new transit sheds and warehouses of these maritime ports meet the modern emergencies, and for that reason the author has undertaken the description of them.

I. WAREHOUSES.

Location.—From what has been said above it is seen that the warehouses are established only in the immediate vicinity of great depths of water.

At Havre, in the basin dock, there is a covered space of 20 meters (65.60 feet) between the edge of the quay wall and the warehouse. At Copenhagen (see Plan I, fig. 6 (No. 97)) the warehouse is separated from the edge of the quay by a wagon way 9 meters (29.52 feet) wide, in which are located two railroad tracks and a loading platform about 4 meters (13.12 feet) wide. At Bremen (Plate I, fig. 3 (No. 97)) and at Trieste (Plate II, fig. 1 (No. 98)) there is found between the warehouse and the bank outside of the wagon way transit sheds with two floors and the wagon way forming a quay. At the free port of Stettin (Plate I (No. 97), fig. 4) the location of the warehouse now in construction is the same as at Bremen and Trieste. At Hamburg there exists only one warehouse built on deep water. There are six compartments closed by massive walls, and the compartments are 660 square meters (7,104 square feet) each, with a total surface of 17,384 square meters (187,119 square feet). The other warehouses of Hamburg are built in the city independently of the port, but are connected with it by water. This is understood by examining Plate III (No. 98).

Dimensions of warehouses.—While formerly the spaces for merchandise were as large as possible they are now considerably reduced, so that there are only about 400 square meters (4,305 square feet) placed between fire walls on account of the danger of fire; so that while formerly there were areas equal to about 1,400 square meters (15,069 square feet) they are now reduced even to 270 square meters (2,906 square feet). The depth of the warehouse is, in general, about 28 meters (91.84 feet), more recently reduced to 24 meters (78.72 feet).

The total area up to the present time at Hamburg covers 41,500 square meters (446,702 square feet), with a useful storage area of 242,000 square meters (2,604,868 square feet).

The warehouses, which have been erected in the free port of Bremen about 1888, show a different plan. Two warehouses, each having 150 meters (492 feet) of length and 23.50 meters (77.08 feet) of width, are divided into compartments of about 300 square meters (3,210 square feet). Two others are arranged with spaces of 740 square meters (7,965 square feet). On the other hand, the warehouse built in 1892 is reduced by subdivisions to 390 square meters (4,197 square feet). At Bremen there is an area covered of 18,590 square meters (199,913 square feet), with a useful warehouse surface of 94,000 square meters (1,005,800 square feet). At Trieste the width of the warehouse of the free port varies from 21 to 33.20 meters (68.88 to 108.90 feet). Fire walls and intermediate passageways divide the warehouse into areas of from 340 to 700 square meters (3,638 to 7,490 square feet). The total surface of ground occupied by these warehouses is about 46,000 square meters (492,200 square feet), and the useful area for warehouseing is 147,500 square meters (1,587,674 square feet). At Copenhagen there has recently been built a warehouse of 94 meters (308.32 feet) length and 25 meters (82 feet) width, having a storage surface of 15,000 square meters (161,459 square feet). This is divided by means of fire walls into three compartments of equal area, each measuring 630 square meters (6,781 square feet).

Interior disposition and character of the constructions of support.—All the new warehouses are massive and built of brick or stone masonry. The most of them comprise cellars, one ground floor, three or four floors, and a loft. The height of the various floors is as follows: The cellar, from 2.50 to 3.40 meters (8.20 to 11.15 feet); ground floor, from 3.20 to 5.50 meters (10.50 to 18.04 feet); first floor, from 2.95 to 4 meters (9.67 to 13.12 feet); second floor, from 2.95 to 3.50 meters (9.67 to 11.48 feet); third floor, from 2.80 to 3.20 meters (9.18 to 10.50 feet); fourth floor, from 2.10 to 3.10 meters (6.88 to 10.17 feet); loft, from 1.20 to 5 meters (3.94 to 16.40 feet).

The loading is as follows: Ground floor, 1,760 to 2,250 kilograms per square meter (360 to 460 pounds per square foot); first floor, 1,200 to 1,800 kilograms per square meter (246 to 369 pounds per square foot); second floor, 1,200 to 1,800 kilograms per square meter (246 to 369 pounds per square foot); third floor, 1,200 to 1,800 kilograms per square meter (246 to 369 pounds per square foot); fourth floor, 1,300 to 1,500 kilograms per square meter (266 to 306 pounds per square foot); loft, 500 to 1,000 kilograms per square meter (102 to 204 pounds per square foot).

Formerly there was a stairway common to two compartments, but more recently, on account of loss by fire, each compartment has its

special stairway isolated and separated by heavy walls from the compartment.

At Bremen the compartments are separated by a passageway 3 meters (9.84 feet) wide, traversing the building from end to end. (See Pl. II (No. 98), fig. 6.) On the street side this corridor connects with a stone stairway, and on the other side with an elevator, which serves all the floors. Both the stairway and elevator are separated from the floors by massive walls. In the front of the passageway on the street side there is a sidewalk 1.50 meters (4.92 feet) wide, and on the opposite side another sidewalk of the same width existing the entire length of the façade. In the cellars the supports are made of brick masonry; in the other floors they are of oak. The cellars are covered by béton arches between the I-beams, and in the other floors there are iron trusses and double floors.

At Hamburg the warehouses are built in blocks of 150 to 200 meters (492 to 656 feet) long, of brick masonry, and divided into smaller compartments by means of fire walls which rise above the roof. Between two consecutive compartments in front of the fire wall is an inclosed stairway leading from the cellar to the loft. This is common to two compartments, and is surrounded by massive walls. The cover of this inclosed stairway under the roof is well protected. Recently there has been given to each of the compartments a separate inclosed stairway. (See Pl. II (No. 98), fig. 5.)

In all of the warehouses columns, protected from fire, are built so that the walls themselves support no weight. In the warehouses of large size there is often a platform for the operation of cleaning and the examination of coffee, which requires a large number of laborers. For this reason, independently of the cellars, the floors and the platforms are protected against fire by means of Monier construction. For connecting adjoining compartments there is at the end of the partition fire-wall a tower inclosing a spiral stairway to which access is had at each story by means of an iron balcony running along the exterior of the wall. (See Plate II (No. 98) fig. 4.) At Copenhagen each compartment is provided on the land side with an inclosed stairway isolated by massive walls. (See Plate II (No. 98) fig. 8.) The columns of all the floors are cast iron. The beams are connected by arches of the Monier construction. On the water side there is built, under the quay and at the height of the cellars, a tunnel or passageway for the movement of merchandise.

Of the free ports under consideration that of Copenhagen is the only one which has a warehouse used as an elevator or silo. This is built at the end of a tongue of land about 60 meters (196.80 feet) wide, and in such a way that there is a wagon way and two railways between the quay wall and the warehouse on each side of it. The warehouse (see Plate II (No. 98) fig. 3) is 50 meters (164 feet) long and 31 meters

(101.68 feet) wide, and is divided lengthwise into three compartments. The compartments laterally comprising a cellar, ground floor, and six other floors are arranged as grain elevators. Two railway tracks traverse this compartment. Above the railway tracks are placed in three rows 36 silos separated by connecting passageways between the two lateral connecting compartments in two groups of 18 wells each. These two groups are isolated by means of a wall built of Monier construction, and separated from the bottom to the top so as to form a warehouse for grain. The wells or cells have a height of 20.50 meters (67.24 feet), and the interior section of about 3.76 meters or of 3.76 by 4.79 meters (12.33 by 15.71 feet). The bottom of these silos is composed of béton supported by |-beams. The silos have a capacity in all of 30,000 tons of grain, and on the floors surrounding them there can be stored 30,000 tons of merchandise. Above the silo there is a lantern comprising three floors in which are installed the plates, doors, the machines for cleaning, as well as the electric motors which run them, and also run the six elevators. For loading the grain directly into the boat there are six loading pipes. The grain brought by boats is lifted by projecting cranes and emptied by means of funnels in longitudinal tunnels situated behind the wall of the quay. The grain is then carried by means of belts to the six transverse tunnels, which lead it to the elevators placed in the cellars.

All the machinery, such as cranes, elevators, windlasses, ventilators, lamps, etc., used in the warehouses is operated by means of electricity furnished from a central station in the free port.

At the warehouse of the free port of Trieste no wood is used in the construction, outside of doors and windows. The walls are of cut stone, or of asphalt, or of brick; the casings of doors and windows are in limestone or sandstone. The interior arrangement differs considerably from that described above. The warehouses are divided into an unequal number of compartments of 15 meters (49.20 feet), mean width, and separated, every two, at the ends by a passageway 5 meters (16.40 feet) wide, traversing the building from end to end. (See Plate II (No. 98) fig. 7.) In each of the passageways of 5 meters (16.40 feet) width there is a hydraulic elevator serving two compartments. The passageways are used particularly to avoid the danger of fire.

Elevators and their installations for operation.—On account of the large amount of merchandise to be handled the judicious arrangement of elevators is of great importance. To raise and place merchandise there is generally employed in warehouses of extensive business only mechanical appliances. As a motive force there is used steam, gas, air under pressure, and electricity. Water under pressure and, more recently, electricity have been recognized as having special advantages for the handling of elevating apparatus. The advantages which water

under pressure presents, ordinarily, at a pressure of 50 atmospheres (750 pounds) are as follows:

1. Perfect security in handling the load up or down, and the ability to stop the movement in any position.
2. Simplicity of construction.
3. Simple maneuvering and without danger, which dispenses with high-priced employees.
4. The expense of construction and of operation is relatively small.
5. The entire operation is without noise.
6. The availability of water under pressure, as is the case at Hamburg and Bremen, for the extinction of fires.

In reference to electricity, the above first five points are applicable, and to them should be added that it is not affected by cold.

The arrangement of the transit sheds and warehouses of the free port of Bremen is based principally on the manipulation of the merchandise by means of cranes. Each compartment has a crane on a projecting portico and by the aid of it the merchandise is taken directly from the floor of the transit shed above the railroads and wagon way upon the platform of the warehouse and upon the first or second floor; or, inversely, from the place of storage and loaded on the car or wagon. There is in each compartment a hydraulic lift running from the cellar to the loft. The cranes, elevators, and windlasses have a power of 1,500 kilograms (3,307 pounds). In order to compensate for the variations of pressure resulting from using the water, there are four accumulators.

At Hamburg, as the movement of merchandise from and to the warehouse is made more by water than by land, all of the warehouses have been provided with capstans and hoists. Along each range of dormer windows of one of the compartments is placed a mechanical windlass of 600 to 750 kilograms (1,323 to 1,653.75 pounds) and a hand windlass. For loads reaching 1,200 kilograms (2,646 pounds) there is generally a hoist going from the ground floor to the loft. The arrangement of the cables of the hydraulic windlass is generally such that the loads can be taken up or sent down either on the land side or on the water side or both at the same time. In order to prevent damages caused by water the hydraulic windlasses are placed inside of massive walls, with a direct discharge into the conduits underneath. The author speaks of the measures taken against fire by means of automatic fire annunciators, which give warning when the temperature is raised above 120° F.

II. TRANSIT SHEDS.

The importance of loading and unloading merchandise rapidly has already been stated above in the introduction of the paper, but in spite of this common object transit sheds present, according to local conditions, very diverse dispositions.

At Bremen each vessel loads and unloads in front of a special transit shed, which is from 135 to 265 meters (442.80 to 869.20 feet) long and from 35 to 40 meters (114.80 to 131.20 feet) wide. Between each two consecutive transit sheds there has been arranged a space of 28 meters (91.84 feet) width to allow for wagons. On the water side, as well as on the land side, between the transit sheds and the warehouse, are hydraulic cranes. The floor of the transit shed is at the level of the wagon way. Each transit shed is surrounded by a loading platform having a width of 2.50 meters (8.20 feet) on the water side and 2 meters (6.56 feet) on the land side. On the latter the roof of the transit shed projects and forms a sort of cover 17 meters (55.76 feet) wide and 30 meters (98.40 feet) long, placed at the level of the street and used by wagons. The installation comprises 31 movable hydraulic cranes on the bank of 1,500 kilograms (3,307.50 pounds) each, one hydraulic fixed crane of 4,000 kilograms (8,820 pounds), and one of 10,000 kilograms (22,050 pounds).

Note that at Hamburg the first basin built upon the wall of the quay was opened to traffic for ships of great draft, provided with movable steam cranes of 1,500 kilograms (3,307.50 pounds), and with hand cranes of 1,000 kilograms (2,205 pounds).

Between 1870 and 1880 there was built a second basin with about 3,100 running meters (10,188 feet) of quay wall provided with steam and hand cranes. The transit sheds were placed 13 meters (42.64 feet) from the edge of the bank, and were from 103 to 224 meters (337.84 to 734.72 feet) long and from 14.76 to 25.70 meters (48.41 to 84.49 feet) wide, with spaces between of 16 meters (52.48 feet). The floor of these transit sheds is at the level of the wagon way. Between the transit sheds and the edge of the quay is a paved wagon way in which are placed the rails for the cranes and for the wagons. On the opposite side of the transit sheds are placed four railway tracks. On the water side the transit sheds are iron; on the land side the walls are wooden walls, rarely masonry. The supporting lateral walls, on the contrary, are always massive and rise to 1.50 meters (4.92 feet) above the roof. The roof is covered with tarred paper.

The author then gives the memorandum of the growth of the installations. At present the maritime traffic is handled along a length of quay 15,390 meters (52,250.40 feet), with 9,000 meters (29,520 feet) of transit sheds, and with a useful covered warehouse area of 229,350 square meters (2,454,045 square feet). The installation of the quay that comprises transit sheds, cranes, railway tracks, wagon ways, etc., has developed according to the demands of the business. As this business and the installations have grown from one stage to another, there is seen to be present three groups of transit shed installations, according to the time in which they are built. (See Plate III (No. 99).) The author then describes in detail the transit sheds used for various kinds of merchandise, particularly for fruit.

The various kinds of cranes, etc., mentioned in the paper, are grouped, as follows, along those parts of the quay bordered by transit sheds: One hundred and forty-eight hand cranes, 1,000 to 2,500 kilograms (2,205 to 5,512.50 pounds); 131 movable steam cranes, 1,500 kilograms (3,307 pounds); 56 movable steam cranes, 2,500 kilograms (5,512.50 pounds); 3 movable steam cranes, 5,000 kilograms (11,025 pounds); 1 movable steam crane, 7,500 kilograms (16,537.50 pounds); 67 movable steam cranes, 2,500 kilograms (5,512.50 pounds); all worked from a central steam station; 24 electric cranes, 2,500 kilograms (5,512.50 pounds).

There are also on the bank, where there are no transit sheds, the following: A fixed hand crane of 40,000 kilograms (88,200 pounds); a steam and a hand crane of 12,500 kilograms (27,562.50 pounds); another of 50,000 kilograms (110,250 pounds); a steam crane of 150,000 kilograms (330,750 pounds).

The transit sheds at Copenhagen are shown on Plate I (No. 97), (fig. 6). The load is 2,250 kilograms per square meter (460 pounds per square foot) on the ground floor, and 1,500 kilograms per square meter (307 pounds per square foot) on the other floors.

At Havre the basins are provided with numerous transit sheds for loading vessels. See Plate II (No. 98), (fig. 2), for the special arrangement of these transit sheds. Those at Trieste are shown in Plate II (No. 98), (fig. 1). The location of all of the important features of the port of Hamburg are shown on Plate III (No. 99).

PAPER BY MESSRS. H. VÉTILLART AND TH. DUCROCQ, OF HAVRE.

On account of the requirements of commerce it is often necessary that goods brought or sent from a port should be held for a more or less length of time in the port and near the docks, either while the merchant is waiting for an opportunity to dispose of the goods that have arrived or waiting for an order to ship those that have been delivered from the interior by rail or by inland navigation. Large warehouses, where the natural productions of the country or manufactures can be warehoused for some time, constitute one of the most important and necessary features of the installation of any port of importance. In order to facilitate commercial operations, the customs laws do not require merchants to pay the customs dues on the merchandise imported until these goods are taken out of the warehouse for consumption. These warehouses, then, are really what is called "bonded warehouses."

The authors propose to describe the warehouse at Havre, and to make some general observations on these features of a port.

I. DESCRIPTION OF THE WAREHOUSE AT HAVRE.

On Plate I (No. 100) are shown the location and the extent of the principal existing warehouse. The authors give a complete table, showing the areas of the different floors, both covered and uncovered, of the warehouses belonging to the various companies at Havre. Summarizing them, these tables show the following: Total area of the cellars, 1,640 square meters (17,652 square feet); total area of ground floor, 205,573 square meters (2,212,787.26 square feet); total area of various floors, 146,268 square meters (1,574,415 square feet); making a total surface in the buildings of 353,481 square meters (3,804,854.26 square feet).

The areas of the roadways, etc., are as follows: Covered ways of access, 107,910 square meters (1,161,542.15 square feet); uncovered ways of access, 192,795 square meters (2,075,236.27 square feet); total, 300,705 square meters (3,236,778.42 square feet); making a grand total of 654,186 square meters (7,041,632.68 square feet).

The authors then go into very considerable detail of the various installations of the different companies, with a brief history of them. That belonging to the Docks and Warehouse Company is shown on Plates II and III (Nos. 101 and 102) the first of which shows the area and plan, and the other sectional elevations of the warehouse transit sheds and covered and uncovered ways of access, with full details, by figures, of heights, widths, etc. Reference to these plates will give all information necessary in regard to the details.

The loads which the various floors can support in the warehouse are as follows: First floor, 1,200 to 1,800 kilos per square meter (245.8 to 368.7 pounds per square foot); second floor, 900 to 1,500 kilos per square meter (184.3 to 307.2 pounds per square foot); third floor, 600 to 1,200 kilos per square meter (122.9 to 245.8 pounds per square foot); fourth floor, 600 to 900 kilos per square meter (122.9 to 184.3 pounds per square foot).

The same mode of construction has been adopted throughout. Generally the fire walls are built entirely of brick masonry. The other parts of the construction, such as the supports, floors, and roofs, are built of wood—oak, pine, and pitch pine. Each covered or uncovered way of access is traversed by a railway track throughout its entire length, parallel to the principal quay of the basin dock. These tracks are connected by turntables with the transverse tracks spaced 60 meters (196.80 feet) apart. The passageways are all paved in such a way as to allow the trucks to be run easily. There are openings left through the floors about 2 meters (6.56 feet) square in all the buildings that have been built since 1860 to allow the packages to be handled between the different floors, generally by mechanical means. The well locks are generally provided with hydraulic jiggers and electric windlasses.

Details are also given of the warehouses of the Havre Company, of public and general warehouses, and of the Red Bridge Docks, and of those of the Tancarville Canal.

II. GENERAL OBSERVATIONS.

Merchandise warehoused in maritime ports as being always intended for loading into vessels should be placed as near as possible to the quays, and should be placed around the basins where the commercial operations take place.

On account of the great cost of land for the warehouses along the quays it is necessary to build them in stories up to three, four, and five, and even more, and to employ machinery for handling the goods to and from the various floors. The authors believe that a general plan, similar to that used at the basin dock at Havre, would be satisfactory, which embraces a transit shed near the quay, a passageway in front between the quay and the transit shed for wagons and for two railroad tracks, a row of buildings back of this passageway separated from each other by covered passageways behind the buildings, a wagon way, and two or more railroad tracks.

I. TRANSIT SHEDS.

The most of the merchandise imported can not be at once, after unloading, placed in the warehouse. It has to submit to examinations and waiting, etc., and during this time it can not be exposed to the weather, especially when it is valuable merchandise intended for warehouses and often of great value. The transit sheds are used for the purpose of protecting the merchandise during this period. The large steamships, such as are used at the present time for maritime transport, are so expensive and the daily costs are so great that it is absolutely essential not to detain them any longer than possible, and this consideration should serve as a most important base for the study of all installations at maritime ports.

It is necessary to have a sufficient area at the quay and under the transit shed to place the entire cargo without interfering with the unloading of the vessel and without any injury to the freight. The width of the transit shed on the northern quay of the basin dock built in 1860 has, on account of the above reasons, become inadequate. If, then, a transit shed on the edge of the quay serves simply to place the freight upon the dock, it ought not to have a less width than 35 meters (114.80 feet). The new transit sheds at Havre in Basin Bellot reached 45.55 meters (149.40 feet) in width.

The tracks mentioned above, in front of and behind the transit shed, should be connected about every 100 or 150 meters (328 or 492 feet)

by switches. The one nearest the quay should be covered by a shed roof extending out from the transit shed. The transit sheds should be closed on all sides in order to protect the goods and prevent theft. On the quay side along their entire length there should be rolling gates, or doors rolling along the tracks placed above, in order to open the transit shed at each hold of a ship. On the other three sides of the transit shed there should be doors cut through the walls about every 25 meters (82 feet). The transit shed should be lighted, independently of the open doors, by windows of ground glass, placed in the roof on the side least exposed to the sun. It is also necessary to have artificial light, preferably electric lights, in order to work during the winter. The floor of the transit sheds is sometimes raised, like those in railroad freight warehouses, to the level of the floor of the cars. This arrangement facilitates in a certain measure the operation of loading the goods upon the cars, but it interferes with the movement of trucks, and the authors advise against this raising of the floors for various reasons, which they give. The floor should be paved with stone or asphalt.

II. WAREHOUSES.

It is very important in their construction to reduce the risks of fire as much as possible. The building should be divided by open ways or wagon ways into groups entirely independent of each other, each building covering a surface of from 3,000 to 4,000 square meters (32,292 to 43,056 square feet). It is desirable that necessary light, entering by windows in the walls, should penetrate to the center of the various floors in order to distinguish perfectly the marks upon the merchandise, and to take out samples where it is necessary. For this reason the width of the building ought not to exceed 25 to 30 meters (82 to 98.40 feet); any greater width will necessitate artificial light. If the building does not exceed this width and a length of 50 to 60 meters (164 to 196.80 feet), it is possible to dispense with fire walls, which always increase the cost of construction and generally interfere with the business of the warehouse, and do not always give a complete guarantee against the propagation of fire. It is also necessary to build the floors of the buildings so as to prevent the passage of fire from one floor to another, and the construction at the points where lifts are placed should have this object in view also.

In the general plan suggested and the descriptions given of the buildings, the authors have had in view the handling of ordinary merchandise. Warehouses for special purposes, such as storage of spirits, wines, vegetable oils, and petroleum, as well as wood and cabinet work, require special arrangement, as well as grain elevators and silos where wheat is stored in bulk.

PAPER BY MR. G. J. DE JONGH, CHIEF ENGINEER OF ROTTERDAM HARBOR WORKS.

WAREHOUSES.

The method by which a port is operated exercises a very important influence upon the arrangement of the warehouses which are intended to hold merchandise during a more or less lengthy period. It is not possible to develop a commercial movement or an extensive navigation in a port if it is not a center of commercial activity. The works themselves can not, in a true sense of the word, give life to a port. They are only inert facilities, to be taken charge of and used by the commerce which already exists. It is necessary to encourage as much as possible the efforts of the commercial men of a port, and not to interfere with their plans of operation by administrative rules and regulations. On the other hand, it is necessary, in order to develop the commerce, to watch to see that no commercial corporation, however powerful it may be, can create a monopoly and move, by its personal interest, to destroy and injure the general interests.

It is from this point of view that the city of Rotterdam has operated its port. With the exception of the Railroad Basin and one commercial station on the right bank of the river, which belongs to the Government, the city is the proprietor of all works of the port, and exploits them as such. It has two large warehouses. One is situated on the left bank of the Maas; it is of masonry construction, having about 4,663 square meters (50,192 square feet) of cellars and 24,550 square meters (264,254 square feet) of floors, with two wooden transit sheds, with an area of about 8,000 square meters (86,111 square feet). The other is on the right bank of the river; it has 6,000 square meters (64,583 square feet) of warehouse surface, and 354 square meters (3,810 square feet) of cellar space. Both are under the continuous watch guard of the customs department. Outside of these two city warehouses there are a number of others, belonging to associations which store merchandise. The city always favors the building of these private warehouses, for however powerful may be the associations that own them they can not raise the price of warehousing, for the city, with its large areas of warehouses at its disposal, can always prevent this tendency, and it is always in a condition to extend its own field of action in this direction. For this purpose the city always has at its disposal lands to be rented for private warehouses.

The large city warehouses are located along the Entrepot Haven, a distance of 13 meters (42.64 feet) from the quay wall. Fig. 1, Plan II (No. 103), shows a cross section of this building. It has a length of 200 meters (656 feet) and a width of 37 meters (121.36 feet); it has one cellar and three floors. Four isolated fire walls project 2 meters (6.56 feet) from the façade and above the roof, separating the build-

ing into five parts, which is, in this way, perfectly protected against the propagation of fire. The cellar is protected from fire; the iron trusses and beams are completely embedded in the béton of the arches in such a way that fire can not reach them. The floors and floor beams of the upper stories are of wood; the columns are cast and the principal beams are of wrought iron. The principal columns and beams are surrounded by béton of the Monier system. The apartments for the lifts are in masonry and protected by iron gates. The side of the building on the water is used entirely for the loading and unloading of vessels and lighters. At the height of the first story, there is a balcony 7 meters (22.96 feet) wide, which, the author states, is entirely too large. Along the quay wall are placed movable hydraulic cranes, which can take the load from a vessel and place it on each floor. If it is necessary to reach by these cranes the third floor, a scaffolding is placed on the second floor, as is shown in the plan referred to. The side of the warehouse opposite the water is arranged for the placing of merchandise on railroad cars and on trucks to facilitate the handling of the goods as much as possible. The level of the ground floor is placed at 0.80 meter (2.62 feet) above the level of the street. The city does not sell any land located within 30 meters (98.40 feet) of the water. In this belt of 30 meters (98.40 feet) the city only gives rental for a long term in such a way as to have the property revert to the city at the end of the lease.

The authors then describe one of the principal warehouses along the Quay Wilhelmina and on the Rhine Basin on the north side. Fig. 3, Plan II (No. 103), shows a cross section of this building and the adjacent quay. On the two sides along the water are placed a belt of transit sheds belonging to the steam navigation companies. In the middle of the space, separated by streets of 25 meters (82 feet) width, are placed the warehouses. These latter are provided with cellars, protected from fire and dry, intended for the extensive commerce and of warehousing of oils and similar goods. As in the case of the city warehouses, the beams are entirely hidden in the béton of the arches. The floors are wooden and the columns are cast or are of wrought iron. The buildings are divided by isolated walls into several definite parts, completely separated one from the other. Each block is about 125 meters (410 feet) long, and the mean width is about 40 meters (131.20 feet). The ground floor is about 0.65 meter (2.13 feet) above the level of the street. Most of the warehouses are provided with electric lifts. The two longitudinal sides of the building have a double-track line, so that there can be easily handled, both loading and unloading, all the goods that arrive both for the railroad and to be taken away by trucks. This kind of a warehouse is very well arranged and easy to operate. The only inconvenience is that it does not permit the direct handling of goods by cranes from the ship into the building. To

make such an arrangement one of the associations has established an iron transit shed of economical construction, represented in fig. 1, Plan III (No. 104). On the front side of the warehouse along its entire length two balconies are placed, on which, by the aid of electric cranes, the merchandise coming from a ship can be loaded directly on to small wagons. Three bridges connect the balconies with the different floors of the principal building. The inconvenience of not being able to establish direct communication with the water is thus removed as far as possible.

Another association has solved the problem in another manner. It has leased a strip of land 12.50 meters (41 feet), with authorization for building a projection over the quay on condition that it will not interfere with the free movement along the quay. A cross section of this building is shown in fig. 2, Plan III (No. 104). The front side of this building is 17.50 meters (57.40 feet) from the water, which position makes it possible to transfer the freight directly from the ship or the lighter to each story of the building. The large disposable space entirely around the building makes it very easy to handle the merchandise, while the movement along the quay is not interfered with.

The author considers there is little change to be suggested in this type of warehouse. He would only recommend that at each floor a continuous balcony be placed behind the building, as is shown in fig. 1, Plan III (No. 104), on the north side of the Rynhaven. An electric plant is used in the warehouse, the power being taken from a central station, the price being 0.52 franc (10 cents) per kilowatt. The author advocates the use of an electric plant for the reason that it is always ready for work; there is nothing to pay for when it is not in use; there are no accidents to fear, as with water under pressure, and in the northern ports is much better than water under pressure, particularly in the cold season of the year. Again, electricity is very economical. There is general satisfaction with the use of electricity in Rotterdam.

TRANSIT SHEDS.

The first transit sheds which were built at Rotterdam for a temporary warehousing for freight brought to them when taken from ships, were built on the railroad basin. There were seven of them, constructed entirely in wood, with roof of asphalt paper (fig. 3, Plan III (No. 104)). It is in isolated portions, which have a length of from 80 to 200 meters (262.40 to 656 feet) with a width of 18.50 meters (60.68 feet). The total length of the transit shed is 960 meters (3,148.80 feet). The floor is 1 meter (3.28 feet) above the level of the ground, and has on the water side a raised platform 3.50 meters (11.48 feet) wide, on which are placed the cranes. On the other side is a raised platform 1 meter (3.28 feet) high, for loading and unloading cars and

trucks. On both sides there are projecting roofs which protect the merchandise against the rain during handling. In front of the elevated platform on the water side is a quay 7.50 meters (24.60 feet) wide, on which a track is placed for the cranes and one railroad track. The quay is furnished with steam cranes of the Brown system. The arms of the cranes turn under the projecting roofs.

The author then states the inconveniences of this special construction. They are: (1) That they are built of wood; (2) that the width is insufficient for large ships which do business at the port; (3) the floors are laid in a mastic of asphalt, which is made soft by the heat and merchandise sinks into it. Again, there is only one railroad track; this is the cause of continual interference and interruption in loading and unloading.

He then gives his views as to how transit sheds should be arranged. (1) Elevated cranes sufficiently high for two railroad tracks underneath. The height of the elevated platform of these cranes should be 10 meters (32.80 feet). The tracks should be connected by switches. The transit sheds should be separated by spaces of not less than 10 meters (32.80 feet) and every 300 or 400 meters (984 or 1,312 feet) these spaces to reach to 80 or 90 meters (262.40 or 295.20 feet), and every now and then the railroad tracks on the water side should be connected with those on the opposite side.

The larger number of transit sheds recently built at Rotterdam are made of corrugated iron. The ends of the buildings, however, are masonry. The distance between the water and the elevated platforms of the transit sheds is now extended to 10 meters (32.80 feet). There are elevated electric cranes, under which there is a space for laying two railroad tracks. This allows the easy loading and unloading of vessels. Nearly all of the transit sheds are provided with wooden floors. The elevation of these transit sheds is shown in figs. 2 and 3, Plan II, No. 103.

PAPER BY C. L. M. LAMBRECHTSEN VAN RITTHEM, DIRECTOR OF PUBLIC WORKS, AMSTERDAM.

Vessels which frequent the ports of the world can be divided into two classes:

(*a*) Those belonging to the regular navigation lines which make a regular service between defined ports, and these constitute at the present time nearly all the steamships. These vessels bring and take away merchandise in packages.

(*b*) Vessels which load in various ports. They are sailing vessels or steam vessels which carry merchandise in packages or in bulk.

Ships of either class ought to find in ports for their loading and unloading suitable and adequate appliances. Vessels of class "a"

require along the quays warehouses simply and economically constructed for holding freight a short time only, where the merchandise can be kept in a dry place for being separated and arranged as soon as possible for transportation by land or water. To accomplish this transit sheds with a platform are suitable.

Vessels of class "b" require massive construction and much more important warehouses for freight to remain a long time or special installations of such a character as the merchandise requires, such as grain elevators, sheds for wood, tanks for petroleum, etc. Vessels bringing goods in bulk, such as minerals and coal, are discharged directly into inland navigation boats or into railroad cars and do not require covered storehouses. The author then goes into the details and examines, successively, (1) the sheds for short storage and (2) extensive or massive constructions for long warehousing.

I. TRANSIT SHEDS.

They should have a clear height of at least 3.50 meters (11.48 feet). The floor should be about 1.10 meters (3.61 feet) above the level of the railroad tracks, or to the height of the floor of the cars. This arrangement facilitates very much the loading and unloading of the wagons and trucks. The length of the sheds depends upon the size of the ships. The cargo ought to be unloaded along a length of quay equal to that of the ship and the height of the unloaded cargo should not very much exceed 2 meters (6.56 feet). Between the side of the shed on the water side and the wall of the quay there ought to be a distance of about 12 meters (39.36 feet). This space can be occupied by an elevated crane, two railroad tracks, and a platform projecting in front of the sheds. If it is thought best, the elevated crane can allow one or two railroad tracks underneath. The side of the shed toward the water can be either entirely open or had better be provided with rolling doors. The location of the moving cranes in front of the sheds depends upon the location of the hatchways of the vessels. In time of rain it is necessary that the merchandise should be put under roof as soon as possible. In order to do that, as the location of the cranes is variable, it is well to place gates along the entire length of the sheds. On the other hand, on the side opposite the water it will suffice to place the gates every 7 to 10 meters (22.96 to 32.80 feet). On the side opposite the water and toward the street there should be placed at least three railroad tracks; that is, one for unloading along the shed, another in reserve for placing cars loaded and empty, and a track for general movement in making up trains. Cross-over switches should be placed every 80 to 100 meters (262.40 to 328 feet) between the first two tracks and every 150 to 200 meters (492 to 656 feet) between the latter two tracks. If there is expected to be a large local movement of wagons and drays it is recommended to leave between

the loading track and the reserve track a clear width of at least 8 meters (26.24 feet) for a wagon way. The tracks between the sheds and the water ought to be connected by cross-over switches or by traverse tables. The shed should have in the interior, as well as the exterior, plenty of light by day and night. Generally lighting equivalent to from 0.8 to 1.5 normal candlepower per square meter (0.7 to 1.2 per square yard) of surface of floor will be sufficient. Plate I (No. 105) gives a cross section of one of the latest sheds built along the Quay of Commerce, at Amsterdam. It satisfies as well as possible the conditions above indicated.

The framing of these sheds is entirely of wood; also the roof is of wood, covered with galvanized iron. The side toward the water has sliding gates the entire length; on the opposite side they are spaced about 9 meters (29.52 feet). All these gates have a framework of iron covered with corrugated iron, with a clear height of 2.60 meters (8.53 feet). The total width of the sheds is about 22.25 meters (72.99 feet) clear space for work. The floors are of pitch pine of 4.25 centimeters (1.67 inches thick); they bear upon longitudinal floor beams of 0.14 by 0.22 meter (5.5 to 8.66 inches), which rest on joists 0.25 by 0.26 meter (9.8 to 10.2 inches) and creosoted piles of 17 meters (55.76 feet). The cost of such a shed 100 meters (328 feet) long is about 122,430 francs, or 55 francs per square meter ($1 per square foot) of covered surface. With good land for a foundation the piles are unnecessary, and the floor can rest directly upon the joists and light masonry walls. In that case the cost is reduced to 44.10 francs per square meter (79 cents per square foot). Buildings intended for warehousing merchandise for a long time brought by ships of class "b" are built with several floors, which present per running meter of length of quay a much greater capacity than the sheds. These warehouses are utilized generally for the storing of merchandise, such as sugar, tobacco, wines, spirits, etc., which are under the charge of the customs.

In the Pays Bas, or Low Countries, there are four kinds of warehouses:

1. Free warehouses, that is, general or public—which are operated by the city or by the state and are under the control of the administration of customs and excises.

2. Free private warehouses. These belong to individuals and are intended for merchandise requiring important custom duties, such as sugars, wines, and spirits. They are under the continual watch guard of the customs in such a way that nothing can be taken in or taken out without permission.

3. Warehouses which are reserved for merchandise which does not pay high duties, such as petroleum, tobacco, and mineral waters. These are scattered throughout the city. They are generally used for warehousing only one kind of goods. They are exploited by individ-

uals, societies, and sometimes by the city, like the petroleum basin at Amsterdam. They are not under the continual watch guard of the customs.

4. Private warehouses. They are, like the free warehouse described under No. 1, places for the deposit of goods in the vicinity of the port. They are nearly all warehouses of five or six floors, built and managed by companies known in the Pay Bas by the name of "veemen." These associations undertake the warehousing of all kinds of merchandise except those which have to pay high duties.

The general dimensions required for these various warehouses are as follows: Between the wall of the quay and the warehouse there ought to be a free space of not less than 8 meters (26.24 feet). This space should have an elevated traveling crane, under which should be a railroad track. On the side opposite the water it is necessary to have at least three tracks, as in the case of the sheds. Between the second track and the warehouse there should be a paved wagon way about 8 meters (26.24 feet) wide and connecting switches arranged as in the case of the sheds. The equipment of the warehouse should consist of cranes on the side of the water, and elevators on the other side. The cranes should be so arranged that they can transfer the merchandise by one movement from the hold of the vessel to the floors of the different stories. The elevators should be able to carry small wagons or cars on which are loaded the merchandise. In a length of 100 meters (328 feet) of warehouse there should be placed three elevated movable cranes and four elevators. The vessels of the present day often have three hatchways. The stairways, as also the elevators, should be placed in independent compartments, which shall not have direct communication with the floors of the various stories. This is for the purpose of avoiding fires. There should also be placed near the stairways and lifts balconies from which a descent can be made from the various stories into the interior of the building.

The entire structure should be, as much as possible, protected against fire. The skeleton of the building in iron should be, as much as possible, isolated by embedding it in the cement on the Monier system of a thickness of 2 centimeters (0.78 inch). The best safeguard against fire, and which is, at the same time, the least costly, is to divide the warehouse into several buildings, completely separated and constructed of materials not easily put on fire. The warehouse, as well as the areas about the buildings, should be well lighted at night. In order to have a good light by day, the width of the buildings should be limited to 30 meters (98.40 feet). The lighting for night work should have 0.8 normal candlepower, English standard, for the different stories, and from 1 to 1.5 normal candlepower for the areas outside. Electric lighting is preferable to all other kinds on condition that it is well installed.

Plan II (No. 106) shows a cross section of a warehouse on the new warehouse basin. Each floor of this building can sustain 2,000 kilograms per square meter (410 pounds per square foot). The total surface of the basin will have 22 hectares (54.36 acres), with a length of quay of 1,700 meters (5,577 feet), and a warehouse floor surface of 221,000 square meters (2,364,700 square feet), and a depth of water of 9 meters (29.52 feet) below the Amsterdam zero. The mean height of the water surface is 0.50 meters (1.64 feet), so that vessels drawing 8.30 meters (27.22 feet) can have access to this basin. If it should become necessary, the depth will be carried to 10 meters (32.80 feet) below the Amsterdam zero. A sorting yard for railroad cars arranged especially for the service of the port is indispensable in all maritime ports of any importance. Connections should be made with this yard with all parts of the port.

Second question.—Relative areas of the different parts of a seaport; docks, quays, railways, warehouses, and sheds; ground reserved for commerce and industry.

PAPER BY M. BUCHHEISTER, HARBOR DIRECTOR OF THE CITY OF HAMBURG.

I. Introduction.

The writer intends to limit himself to commercial ports, and to give general outlines only, referring to some special examples as illustrations, and then to go at length into the details of the port of Hamburg. The general plan of the commercial ports differs in different nations, and has great diversity of form, due to the methods of commercial movement, and the different means of disposing of the freight received from vessels. For that reason it is necessary, in the first place, to analyze the nature of the commercial movement and the geographic position of the ports, in order to work out, as near as possible, a common formula from the many different conditions.

II. Movement of Navigation.

The writer lays it down as a general idea that the ship itself does not determine the character of the port, for the reason that some of the important seaports of the world have practically no installations for handling freight, the ships anchoring in the open sea and discharging, by means of lighters, to moles and piers, or even the open beach at the shore. It may be said, also, that vessels and boats of various kinds that navigate rivers often handle their business at ports of the most simple form and plans.

RAILROADS.

This modern agent of transportation has greatly changed the method of handling freight, and has given a special characteristic to ports built or enlarged in recent years.

LOCAL TRAFFIC.

A second and important factor in the general arrangement of maritime ports is the local movement of the commerce, for the reason that this exercises an important influence on the general form and installations of the port. By "local traffic" is not meant the direct movement into the interior by vessel or by railroad car, but the business of the city itself, particularly in reference to warehouses.

SITUATION.

The third factor to take into account is the topographic situation of the port. While this is given as a third factor, it is, in the opinion of the writer, of material importance.

The land conditions have always played a very important rôle in the plan and general arrangement of a port. The port can be situated either directly on a seacoast, or some river, bay, or gulf, or, very often, far in the interior on some river or maritime canal.

Finally, ports depend, in their general plan, largely upon diverse conditions, depending upon their location, more or less removed from the sea, the régime of the oceans, the action of winds and of tides, and the general conformation of the shore line. In reference to the latter, there are two characteristic ports, one an open port or tidal port, and the other an inclosed port, or dock port.

The nature of the soil, whether alluvial or diluvial or rocky, plays an important part in the arrangement of the basins, either natural or artificial and the adoption of long, consolidated quays, or of jetties bordered by walls, or by the construction of moles and piers; therefore it is seen that the topographic and geologic situation exercises a decisive influence upon the morphology of the elementary features of a port.

THE OCEAN VESSEL AS A UNIT OF MEASURE.

Taking account of all of the above considerations, as well as many others which are found in facts of history or in national or commercial politics of peoples, we must come to the conclusion that each port ought to have a plan peculiar to itself which separates itself by its special characteristics from all others.

The form of installations of a seaport, the relation between the water and land areas, the grouping of the quays, the development and the capacity of the sheds and the warehouses, and the number and the power of cranes of all kinds and their relation to the network of rail-

roads vary in different places. In reference to the ocean vessels there ought to be taken into consideration three factors, their dimensions, their cargo, and their financial relations. These three factors have a very intimate connection between themselves. The dimensions of vessels increase from year to year and their draft in the same ratio.

The author then gives, from specifications of the port of Hamburg, tables which show very plainly the increase in the size of vessels. The tables extend from 1846 to 1895. The number of seagoing vessels increased from 3,763 at the former year to 8,928 in the latter year. The register tons increased from 461,770 tons to 5,954,214 tons; the average register tonnage from 123 to 667 tons.

In reference to the draft, which is shown in another table, there has also been a very considerable increase. This table extends from 1888 to 1897. Briefly, it gives the following: In the former year there were 380 vessels of 6 meters (19.68 feet) draft; in the latter 931; 224 in the former year of 6.30 meters (20.66 feet), and 698 in the latter year; 13 of 6.90 meters (22.63 feet) in the former year, and 245 in the latter; 1 of 7.50 (24.60 feet) in the former year, and 52 in the latter year. A draft of 7.80 meters (25.58 feet) did not appear at the port until 1895 when there were 5 of such draft. In 1897 there were 19.

The increase in the size of large vessels requires an increase in water areas for the purpose of handling the vessels. The passageways leading into inclosed docks have to be enlarged; and, in fact, all the installations, the quays, the cranes, and other apparatus. The transit sheds have to be increased to keep pace with the development of traffic resulting from the employment of larger ships. On the other hand there is required a great development of railroad rolling stock, also a greater development in the interior navigation, also in workshops, dry docks, and all other installations.

The loading of vessels is a second factor which exercises a very positive influence upon the arrangement of a port. Certain cargoes having great value require, even when upon the quays, to be placed under transit sheds that are well covered. On the other hand, bulk merchandise of little value can remain without inconvenience in the open air on uncovered quays.

The third question of the financial relations of a port is a very complex one. It takes in at once the essential point whether a ship will always find at the port a sufficient amount of return freight or whether it must depart in ballast. While sailing vessels can handle their freight in open water with their own windlasses and load and unload with lighters alongside, steamers generally on the other hand have to go alongside of quays well equipped, where the loading and unloading can be done with great celerity.

From what has been stated above, the conclusion is reached that the ship itself on one hand and its cargo on the other hand form the

elements of measurement, a unit of measure, which allows of an analysis and a comparison. From this general subject the author passes to an analytical subject of the different parts of a maritime port and

MEANS OF ACCESS.

This refers to the entrance or navigable passes by which vessels reach the port. Some ports have entrance channels of great dimensions and of exceptional depth, like, for instance, the port of New York, which is six-tenths of a mile wide, in great contrast to the entrance channels of a number of ports, where the means of access has had to be made artificially, such as the ship canals to reach Amsterdam and Manchester, the dimensions of which the author gives, and refers to the necessity for increasing, from time to time, the tidal locks for reaching tidal ports, and instances that at Ymuiden, which now has 10 meters (32.80 feet) depth and 225 meters (738 feet) length, and Bremerhaven, where the width is 28 meters (91.84 feet). Nearly always ports situated on coves and creeks have naturally very narrow, troublesome entrances, which can only, by large expense and a great deal of work, be made practicable for modern maritime commerce, and that by works of various kinds, such as dredging, river correction, etc. Among those ports found in such locations there might be mentioned London, Antwerp, Rotterdam, Bremen, Hamburg and Stettin. The minimum width of practicable entrance may be between 70 and 150 meters (229.60 and 492 feet), but for a large commercial port a width of from 200 to 300 meters (656 to 984 feet) is indispensable, especially when, outside of the question of maritime navigation, the river or the entrance channel has still to serve as a place for an important movement of sailing vessels, coasters, fishing boats or inland navigation boats.

THE ANCHORAGE AND THE OUTSIDE PORT.

Sometimes the entrance channel to a maritime port constitutes its anchorage, but more frequently the port rests immediately upon an anchorage or an outside port. No general rule can be laid down for the dimensions of anchorages, because each port has its own individual conditions. It may be laid down as a rule, however, that every ship coming to an anchorage bar requires a sufficient water area around itself to permit it to have lighters alongside and to receive and unload cargo, also floating elevators, if they are needed.

THE CONSOLIDATED SHORE OF A PORT.

Every vessel should have in such a port, for itself, a length of from 80 to 120 meters (262.40 to 393.60 feet).

PIERS.

When the natural bank does not suffice for the commerce of a port, various methods are adopted for making the port convenient. The most simple method is to push out from the land pile piers or jetties, giving them such dimensions as the size of vessels arriving at the port requires.

The author again refers to the port of New York as an illustration of this plan. The length of the pier is fixed according to the length of the ocean vessel. It varies between 40 meters (131.20 feet) as a minimum up to 200 meters (656 feet) as a maximum. The normal length of the largest piers at the port of New York is from 140 to 170 meters (459.20 to 557.60 feet). The width of piers varies from 6 meters (19.68 feet) to 40 and 50 meters (131.20 to 164 feet). The widest piers at New York have a mean width of from 18 to 25 meters (59.04 to 82 feet). The area of water between two piers ought, in general, to permit two vessels of a good size to tie up to the piers side by side. Sometimes it is necessary that between them there should be a place for boats from the interior, but generally these latter can be placed on the other side of the pier, the pier in that connection forming an intermediary between the ocean vessel and the interior navigation vessel. The width of water area between two piers can vary from 25 meters (82 feet) (when it is intended for only one vessel) to 60 meters (196.80 feet) and still greater. The mean width is generally between 33 and 50 meters (108.24 to 164 feet). Generally the relation, under normal conditions, between the area of land and of water is as 1 to 2.

BASIN PORTS, TIDAL PORTS, AND DOCK PORTS.

The installation of a port will be arranged on a very different plan than those above described forming a great number of piers extending out from the shore, when the arrangement permits of protecting, in each part of the port, a large number of vessels of all sizes. This plan forms what is called a "basin" port, the banks of which are formed by long quays and jetties; still a port so planned can easily have piers extending into the basins.

In planning a port, it is an important matter to ascertain the advantages and disadvantages of pier ports, like New York, for instance, and basin ports, in order to form a conclusion as to which method is better. The basins, themselves, are nearly always artificially deepened; the quays, which border them, are formed by an artificial elevation of the land. We find this type in river alluviums, where the soil in its upper layers generally offers a foundation for heavy constructions.

There are two kinds of basin ports, one opened directly to the harbor, and the other absolutely closed to the tide. The latter is called a dock

port. The establishment of these dock ports is often a necessity demanded by the hydrographic conditions of the place, such as the rise of the tides, the distance of the port from the sea, or from a wide navigable pass. From this point of view dock ports may be considered as a necessary evil; yet it is true that, while they are an inconvenience on the score of economy, they are very advantageous. The dock port is particularly found, to a great extent, in England, and in earlier days at Hamburg; although, later, the basin port was adopted.

ENTRANCE OF PORTS.

The entrance should be directed in general toward the sea. It should be so planned and executed as to offer to vessels an easy and sure passageway into the basin. In establishing the entrance, there should be taken into account the direction of the current and of the prevailing winds. If the basins have an outer port, it is necessary to take into account the access from the sea to this outer port.

Certain dock ports have a single entrance arranged in groups of locks, so as to permit the passage of vessels of various sizes, each entrance being designed for a special size of vessel. An example of this plan is found at Liverpool, and in this instance the necessary depth of water for the largest vessels is obtained by special means—raising the water artificially in a group of basins. This plan is also found at Manchester and Amsterdam, where vessels, with a draft of water of 9 meters (29.52 feet), can now maneuver. The width of the entrance to an open tidal port must evidently be greater than that into dock ports.

PORT BASINS.

The dimensions of basins are usually fixed by the work they are designed to accomplish. The length of basins is calculated for a good number of ships, and varies between 300 and 3,000 meters (984 and 9,840 feet). The width of the basins depends upon the manner in which the merchandise is handled. When the vessels load and unload directly at quays, a width of 100 to 200 meters (328 to 656 feet) will suffice generally. If the basin serves not only the purpose of handling cargoes from the ship to the quay and vice versa, but also from one vessel to another, or by means of lighters, the width of the basin will have to be increased in proportion. With a double range of anchorages placed in open water, the basin should be, at least, 200 meters (656 feet) wide, with two double ranges of anchorage placed 300 meters (984 feet) apart. That part of the port of Hamburg used by sailing vessels is an example of this latter case.

INSTALLATION OF QUAYS.

The arrangement of quays depends greatly upon the method of handling the cargo, whether it is to remain for any length of time upon the quay, either covered or uncovered, or taken to the warehouse.

SIZE OF THE QUAYS.

This depends largely upon whether there are transit sheds or warehouses built on the quay or placed at some distance inland. The width, if simply quays, will vary from 60 to 80 meters (196.80 to 262.40 feet), and for quays in the form of jetties, from 110 to 160 meters (360.80 to 524.80 feet). These greater widths are for the largest size of modern steamers. These quays are sufficient for from three to six railroad tracks on each quay, and for transit sheds of from 15 to 40 meters (49.20 to 131.20 feet) in width.

If a comparison is made between the width of quays and the width of basins given above, it is found that the relation between the land areas and the water areas are from 1 to 1 to 1 to 2.

TRANSIT SHEDS, CRANES, TRACKS, AND CARRIAGE WAYS.

Upon the subject of forming the different parts of quay installations, it should be stated that any rules laid down can only apply in a general way.

Transit sheds on quays of the widths above mentioned have a length of from 80 to 250 meters (262.40 to 820 feet), corresponding to the length of from one to three ocean vessels. The transit sheds are sometimes absolutely open and protected only by the roof. The movable cranes, which are, in general, of about 3,000 kilograms (6,615 pounds capacity—sometimes up to 10,000 kilograms (22,050 pounds), but rarely—are generally placed on rolling supports. These cranes are operated by hydraulic pressure, or steam, or preferably in these latter days, by electricity.

The port of Hamburg has at the present time the most powerful commercial crane in the world. It is intended to handle loads up to 150,000 kilograms (330,750 pounds).

In reference to the railroad track, the former method of turntables and of traverse tables are no longer used, the ordinary switches being employed.

WAREHOUSES.

Generally they do not constitute an integral part of a seaport but belong to private individuals and companies; consequently their location can not be determined by any special rule. They are sometimes near quays and sometimes placed in cities, either alongside of railroad tracks or near canals.

The author then takes up the subject of river navigation in connection with a port and industrial installations. He then comes to the special subject:

III. The Port of Hamburg.

The general principles and rules laid down in the paper are illustrated fully by describing the methods at Hamburg.

1. Its situation and means of access to it, and the general features of the port.

It is located on the Elbe 105 kilometers (65.1 miles) in the interior. The river has a mean tidal rise of 1.90 meters (6.23 feet). The largest ships can enter the port, taking advantage of the tide. This channel is not altogether a natural one, but has been obtained by dredging during the last forty years, and in the Lower Elbe, near Blankenese, where there are found troublesome river bars, the channel there has had a minimum width of 150 meters (492 feet).

Vessels having a draft of 7½ meters (24.61 feet) can reach Hamburg. Of all of the vessels visiting the port in latter years the draft of which exceeds 6.30 meters (20.66 feet), only 2 per cent have been obliged to lighter in the lower part of the river about 30 miles below Hamburg.

BASINS AND QUAYS.

Up to 1866 the port facilities of Hamburg were limited to strong ranges of piles and anchored buoys, alongside of which the vessels were placed, and the cargoes were handled by means of lighters. These lighters or small canal boats navigated the network of canals in the city itself, taking the cargo from the ships to the warehouses located on these canals. In 1885 there was a very important growth in the general development of the port. In that year the territory comprising the city was admitted into the German Confederation and a free port was established, and at the present time there are still further extensions of commercial facilities now being carried out. (See Plan I, No. 110.) The author then gives the dates at which the various basins were opened up.

TRANSIT SHEDS AND WAREHOUSES.

All of the quays used for maritime navigation are provided with transit sheds, where all the various navigation movements are carried on. The transit sheds have a width of from 15 to 35 meters (49.20 to 114.80 feet); the length varies from 110 to 260 meters (360.80 to 853.02 feet). The floor is raised 1.20 meters (3.93 feet) above the pavement of the wagon ways and the tracks.

There are only two warehouses on the quays, one having six and the other twelve floors, with a total floor area of 32,400 square meters (348,750 square feet). The other warehouses are located on the canals in the city, consequently many of the vessels load and unload in open water in the river, made fast to buoys. The location of these various anchorages is shown on Plan II (No. 111).

The author then describes other installations, railroads, cranes, etc., and refers for details of these cranes to Plan II. He then enters upon a statement of the size of the different parts of the port, and gives

several pages of detailed tables to which reference is made in case anyone desires to examine into the matter further. The relations between the length and areas of quays and the areas of water surfaces and other relations of interest are fully discussed by an analysis of these lengthy tables.

The author then describes the methods of operating the river parts of the port, and closes his paper with a comparison with other ports, and, for the purpose of general comparison, shows the ports of Liverpool, Rotterdam, Amsterdam, and Hamburg on a separate chart III (No. 112).

PAPER BY MR. A. D. GUÉRARD, CHIEF ENGINEER OF HARBOR WORKS, MARSEILLES.

The means employed at this day for sea transport represent a large capital and demand and require great expense.[1] The rate of freight, on the other hand, has been greatly reduced.[2]

In order for the shippers and owners of vessels to realize a profit the vessels ought to make their voyages with the greatest possible speed, also the operations of anchorage, loading, and unloading, in order that the time spent in port may be reduced to its extreme limit. This result can be obtained only upon the condition that, independently of the necessary depth of water, which in these days ought not to be less than 8 meters (26.24 feet), independently of facilities of access, anchorage, etc., the ships ought to find in the ports basins of operation where they can conveniently make all necessary movements with the quays alongside of which they can lie, and of a development sufficiently large. It is necessary that the quays should be provided with mechanical appliances permitting the rapid and economical unloading and loading, and that the areas for the receiving of freight should be sufficiently great so that the freight can be placed either under cover or in the open air. There should be public highways, railroad tracks, and roads for drays sufficient for the rapid handling of the business. On account of the considerable lowering of the cost of transportation by sea the advantages resulting from the geographical situation of

[1] An average made a few years past to ascertain the cost of a number of French steamers, the net tonnage of which ran from 700 to 2,000, and the speed from 10 to 12 knots, was as follows: Cost of building, about 700 francs per net ton ($140); running expenses per ton and per day, first, in the ports, 0.30 to 0.65 francs (6 to 13 cents); second, at sea, 1.15 to 1.50 francs (23 to 30 cents). These figures include interest and amortization on a basis of 10 to 12 per cent per annum; also maintenance, repairs, provisioning, general expenses, as well as port pilotage, towing, hauling, customs, insurance, etc., expenses.

[2] The freight from Cardiff to Bombay, a distance of 11,605 kilometers (7,206 miles) is 14.35 francs (0.4 mill per ton mile). The rate from Bombay to London and the continental ports is about 18 francs (0.6 mill per ton mile).

ports have lost their importance. The cost of merchandise itself has greatly decreased. From 1872 to 1892, twenty years, the value of merchandise imported and exported in the port of Marseilles has decreased, on an average, 25 per cent.

The relative extent of the basin and quay areas is not the only thing to be considered in the arrangement of a port. The development of available quays for the operations of unloading and loading in relation to the areas of the water and in basins and the areas of the land along the quays is an element of prime importance. The arrangement of ports varies according to the local circumstances, the configuration of the shores, the nature of the soil, the régime of water and of the alluvial matters, the régime of the winds, the destination and kind of navigations, the kind of ships, the special nature of the operations and of kinds of merchandise, also the means of communication with the interior country. There are no precise rules for tracing out the lines of and arranging ports, neither for the arrangement of the facilities.

Form of the Basins.

The relative size of basins depends upon their form. At a period when navigation was performed exclusively by means of sailing vessels, where transportation into the interior was done by carts or by boats drawn by men or by horses, the principal care was to arrange the various areas of the harbors so that the vessels would be protected from winds and from the seaway, and to prevent alluvial matters from filling up the harbors. The vessels, once anchored in the basin, unloaded their cargoes and waited patiently for the consignees to come and take away the merchandise. The unloading was done by manual labor on lighters, and when the freight was received at the shore of the basins it was loaded on cars. The general configuration of the surrounding shores determined the form to give to the basins. Most generally it was rectangular; that form was the general contour up to the time when the necessity for increasing the quay development in reference to the water surface was very appreciably felt. At present it is considered that operating basins ought to have, as much as possible, a sufficient space for vessels to swing, forming a sort of vestibule, upon which borders the basins into which the ships move to be made fast to the quays. Sometimes the vestibule lay at the entrance of the basin, as at Dunkirk, Tilbury docks, London, Glasgow (Queen's and Cessnock dock), at Antwerp, American Basin at Leith, and Edinburgh dock. Sometimes it extended the whole length of the basin, and the docks were arranged laterally, like the Victoria dock at London (the first of the kind which was ever constructed), at Marseilles, Trieste, Fiume, and Manchester. In the ports established on the banks of rivers or on maritime canals there are only wet docks, the river and the canal playing the rôle of a basin of evolutions, and of unloading

and loading operations at the same time, as at Hamburg, Bremen, Rotterdam, and Port Said. At Genoa there is an interesting variety of the second and third types combined. It consists of an immense central basin having practically the form of a semicircle, along the border of which are cut a series of basins converging toward the center. In tidal ports, where the height of the tides is suitable, there are floating basins, or elsewhere basins are opened freely and access to them is possible at all hours.

The above-cited examples show that the configuration of the ports play a preponderating part in tracing out the lines of the port and the interior arrangements, particularly of the basins. At Marseilles, e. g., there will be an advantage, in point of view of the proportional development of the quays, to enlarge the basins still more, so as to increase only a little the length of the sea wall, for the additional length of the sea wall would protect a large quay development. The sea wall is a costly work, the price of which increases with very considerable rapidity with the depth, and increases all the more rapidly as it is removed from the bank. The present sea wall of the outside port at Marseilles is built in a depth of 29 meters (95.12 feet). To obtain in the Marseilles basin the smooth water which is necessary, in spite of the violence of the most frequent winds (mistral) which blow in one direction, the basins can not have a length of more than 600 meters (1,968 feet). Finally, the necessity of arranging between the basin quays and the railroad and the navigable passageways which serve the port suitable connections, makes an element in the problem of very great importance, not only in choosing places for basins, but still further in their outline.

1. The Outline of the Quays.

It is necessary that vessels placed at a quay should have their sides parallel to it. Curvilinear form, either concave or convex, ought to be avoided. Those of less than 200 meters (656 feet) radius ought to be avoided. The length of the rectilinear parts should be at least equal to that of the vessels.

2. Width of Quays.

The area of the quays, or, better said, their width, depends on the use to which they are to be put; that is, the character of the merchandise to be loaded or unloaded, the kinds of operation required by these kinds of merchandise, and the means employed for transporting them on arrival, and, in a certain measure, the size and capacity for vessels, etc. For example: It is not necessary to give to a quay which is intended for the landing of passengers or sheep, or, still more, of minerals and coal intended for manufactures in the interior, and to be carried by railroad, a width as great as a quay on which are to be

unloaded woolens, cottons, cereals, grains, and merchandise, which have to be examined and sampled, or placed in proper condition, or dried, before being loaded. When merchandise is brought or taken away by railroad or by drays there is required more room than if handled by other means of transportation, on account of the space necessary for either the railroad tracks or for the roadways. The extent of the quay areas depends also, to a certain extent, upon the form and size of the ships which are brought to the quays; so that, for instance, sailing vessels require less room than steamers because their operations are conducted less rapidly. It is necessary to have larger areas for great ships than for small ones, because the quantity of merchandise unloaded per running meter of quay is much greater in the first case than the latter.

The arrangement also should be varied according to the situation of the quays in respect to the city. When a quay is in the city itself, and has around it the buildings in which the shippers and merchants have their offices, warehouses, etc., it is unnecessary to have offices upon the quays; thus the buildings required for them are not needed. It is important to relieve the quay from all movement of people, or of ordinary business which is not directly related with the business of the port; in other words, to admit upon the quays only those roads which serve the transport of persons and merchandise connected with the port. The railroad stations ought to be, as much as possible, outside of the quay space, because they only serve to hinder the operations of the port.

When the width of a quay is spoken of it should be understood that it means a quay unincumbered with any outside business, or lines of railroads, or railroad stations. When a port is especially used for certain kinds of merchandise—e. g., a port exclusively used for the exportation of coal, as at Cardiff, and of minerals, as at Bilbao—it is possible to proportion the width of the quay exactly according to the importance of the traffic; but it is not generally so in other cases, even in the case where certain quays should be used exclusively for one particular kind of traffic, because this traffic is susceptible of great variations.

For instance: the port of Marseilles formerly received, about twenty years ago, about 455,000 tons of mineral per annum, and there was one side of the pier specially arranged for this business. This traffic has almost entirely disappeared on account of the changes in the metallurgical industry, so that the tonnage of iron ore imported per annum does not reach now more than 15,000 tons. It has been, therefore, necessary to change the purpose of this pier to that of handling cereals and other merchandise. Another example is in the operations for handling coal in the port of Marseilles, where it has been necessary to place the quays and coal yards at a distance from the city

on account of the inconvenience of dust, etc.; and yet on account of the extension of the port from time to time it has been necessary to relocate the quay and yards in several different places.

3. Arrangement of a Quay.

The quays of a port are the places where the interchange between maritime navigation and interior lines of transport, rail or water, takes place. It would seem that the problem of quay arrangement is best solved by establishing a wagon way and railroad tracks near the edge of the quay, because, by this arrangement, the exchange of merchandise between the ship and the car, or the dray, is done immediately without other transportation; but this seeming advantage is not the rule. The merchandise which makes up the cargo of a ship having been intrusted to the captain of the vessel, an account has to be rendered by him, upon unloading, of an equal quantity and without danger to the cargo; consequently the merchandise has to be examined, weighed, and verified. This may be done by the consignee, or by the custom-house, or by the assurers, and for these operations it is necessary that the goods should be arranged along the quay, package by package, or placed in sacks if they have come in bulk, before being placed upon the cars or into warehouses. It is the same case in loading; the captain of the vessel will not take the responsibility of merchandise unless he can verify it. If the tracks are laid along the edge of a quay the depot for the merchandise must be placed from 10 to 12 meters (32.80 to 39.36 feet) from the edge of the quay, so that the expense of handling generally increases.

At Marseilles, along the basin quays of the maritime station and the national basin, which have been provided with movable cranes on rails, it has been considered necessary, after a study in all ports of Europe, of leaving between the edge of the quay and the place where the goods are disposed, covered or not, a space of seven meters (22.96 feet), on which the cranes place the packages, which are then moved by manual labor to the sheds. This space is sufficient to place the track for the cranes and the railroad track. At Marseilles, at the maritime station and on the national basin, the transit sheds are 25 and 37 meters (80 to 121.36 feet) wide, respectively. The drays have free access under the sheds; the railroad tracks are outside. Experience has shown that a width of 25 meters (82 feet), although convenient, is not as convenient as a width of 30 meters (98.40 feet). The width of 37 meters (121.36 feet), above mentioned, is for the large ships of the Indian or North American lines which arrive with complete cargoes of 5,000 tons or over. In basins of the maritime station, and in the national basin, the piers are 90 meters (295.20 feet) wide, with transit sheds 25 meters (82 feet) wide. In the basin now in construction next to the national basin the piers have not less than

100 meters' (328 feet) width, two of them being 100 meters (328 feet) wide and the third 110 meters (360.80 feet), in order to have sheds 30 to 35 meters (98.40 to 114.80 feet) of useful width.

4. Railroad Tracks.

Behind and along the transit sheds are placed the railroad tracks and outside of them the wagon way. The number of railroad tracks depends upon the importance of the traffic and, in a certain degree, upon its character. At Marseilles, where the merchandise tonnage exchanged between the ship and railroad does not reach one-sixth of the total tonnage of the port, 2 tracks are sufficient, and 1 for general movement; that is, 3 in all. The circulating track is sufficiently distant from the operating tracks to not be in the way of the passage of cars. On the bank quay of the basin now in construction there is to be a width of 68 meters (223.04 feet); that is—

	Meters. Feet.
A free space between the edge of the quay and the transit sheds outside of	7= 22.96
Transit shed, including the wall	31=101.68
Railroad tracks, with side space	14= 45.92
Carriage way	11= 36.08
Sidewalk	5= 16.40
Total	68=223.04

If there are 4 tracks and a line of tramways, it is necessary to increase this width to 74 or 75 meters (242.72 to 246 feet). The transit sheds are intended to protect the merchandise at the time of unloading, during examination, and before loading it. The length of time for keeping the merchandise under the transit sheds should not exceed five to eight days, according to the importance of the cargo, and not more than five days if it has to be loaded. If it has to remain a longer time the transit shed should be turned into a warehouse.

An arrangement which has been adopted in several ports—among others Liverpool, Glasgow, Copenhagen, and Marseilles, and which gives in the last port very good results—consists in building the warehouses with 1 story and an exterior gallery. When warehouses have to be established along the quays for warehousing merchandise the width of the quays must be considerably increased. These arrangements vary a great deal, according to circumstances. One of the plans very convenient is, in a general way, to back up the warehouse to the transit shed and to make the ground floor of the former a continuation of the latter. The width of the latter can then be reduced to 15 or 20 meters (49.20 to 65.60 feet), the warehouse to have 30 to 35 meters (98.40 to 114.80 feet) width. It is built in one or more stories, according to the importance of the freight to be placed there, on the basis of 800 kilograms per square meter (164 pounds per square

foot) on the ground floor and 700 kilograms per square meter (144 pounds per square foot) on the upper floors.

The width of the piers in this case should not be less than 140 meters (459.20 feet), arranged as follows:

	Meters.	Feet.
Free space along the edge of the quay	7=	22.96
Shed and warehouse	48=	157.44
Tracks and road	30=	98.40
Shed warehouse	48=	157.44
Free space along the edge of the quay	7=	22.96
Total	140=	459.20

The width of the bank quay should be 100 meters (328.80 feet); that is—

	Meters.	Feet.
Free space along the edge of the quay	7=	22.96
Shed warehouse	55=	180.40
Tracks	18=	59.04
Carriageway with tramway	15=	49.20
Sidewalk	5=	16.40
Total	100=	328.00

The author then goes into very considerable detail to explain the proper arrangement for tracks outside, sorting yards, etc. He thinks that sometimes there is too much space given to the railroad tracks. He gives in the résumé what he considers the best relations in reference to quays, and the following table does not, of course, relate to special business or to certain kinds of merchandise.

The widths suggested are as follows: (1) Without warehouses: Quays, 70 meters (229.60 feet) wide; piers have a length of 250 to 350 meters (820 to 1,148 feet) and a width of 100 to 110 meters (328 to 360.80 feet). (2) With warehouses: Quays about 100 meters (328 feet) wide; piers have a length of 250 to 350 meters (820 to 1,148 feet) and a width of 140 meters (459.20 feet).

5. Relative Extent of the Water Areas of Basins and of the Areas of Quays in Relation to the Development of Quays.

The surface of the water in tidal basins most recently constructed is generally from 8 to 15 hectares, (19.76 to 37.05 acres). It sometimes reaches a much greater extent. The Royal Albert Dock at London has 36 hectares (88.92 acres). These dimensions are not so very much greater than those of the basins of the new port of Marseilles. Those of Lazaret and d'Arenc do not measure altogether over 18.16 hectares (44.85 acres); the Joliette basin, 20 hectares (49.40 acres); the basin of the maritime station, 18 hectares (44.46 acres), and, finally, the national basin, 41.85 hectares (103.37 acres). But the development of quays relative to the water areas is much greater in tidal basins than in open basins. In the former case it varies, according to the dimensions and

form, from 140 to 350 square meters per hectare (606 to 1,525 square feet per acre). At Antwerp it is 159 square meters per hectare (688 square feet per acre); at Liverpool, considering the whole port, 267 square meters per hectare (1,163 square feet per acre), while in the port of Marseilles it does not exceed 142 square meters per hectare (615 square feet per acre), and it is much less in the smaller basins. In tidal basins the handling of ships is done by towing. The development of the quays in relation to the surface of the water is about twice as great as in the Marseilles basins, but the maneuvering of the ships required much more time in former years—sometimes hours and even days for a ship to take her place at the quay. In the port of Marseilles the departure of vessels, whatever the basin where the ship has been placed, is done in twenty minutes, or half an hour at least, from the time when the lines are cast off at the entrance. This is a great advantage, especially in the case of a port of "call."

In the port of Marseilles quays have the following widths, which in tabular form it is unnecessary to give in this résumé: The bank quay, running from 47 to 60 meters (154.16 to 196.80 feet); the side quay, 19.30 meters (63.30 feet), and the piers with warehouses, 120 to 135 meters (393.60 to 442.80 feet). A much more extended table is given for each of the basins, showing the water area, the length of quays and their area for various kinds of merchandise, and those which are reserved for the movement of vessels. Some of the details are given in the following:

	Square meters.	Square feet.
Water areas available for stationing vessels and for loading and unloading	1,613,782	=17,370,548.00
Repair basins	62,405	= 671,727.00
Passageways and parts of the port protected but not available for placing vessels and for port operations	66,858	= 719,659.00
Outside ports	204,613	= 2,202,454.00
Total	1,947,658	=20,964,388.00

	Meters.	Feet.
Quay development available for unloading and loading	15,907	= 52,174.96
Around repair basins	1,060	= 3,476.80
On passageways or parts of the port not available for loading and unloading	2,773	= 9,095.44
Outside ports	1,566	= 5,136.48
Total	21,306	= 69,883.68

	Square meters.	Square feet.
Quay areas, tracks, and passageways	565,687	= 6,089,054.00
For depots for merchandise	385,746	= 4,152,169.00
Total	951,433	=10,241,223.00

The above table is based upon the estimated urface of the Pinède basin, now under construction. Considering the whole surface of the present port—that is, water surface, quay surface, dry docks, repair

basins, etc.—there are 2,317,378 square meters (24,944,256.79 square feet). After the Pinède basin is completed there will be 2,998,071 square meters (32,271,236.24 square feet). The author works out some very interesting relations from the various figures given above and the more detailed figures given in the tables.

For instance, it is seen that, taking into account the whole port, the water area of operating basins of outside ports and repair basins is 124.74 hectares (308.11 acres) and the development of the quay 15,131 meters (49,642.78 feet), which gives a mean of 82.44 square meters (887.37 square feet) per running meter of quay. The total quay area is 66.52 hectares (164.30 acres), of which 38.68 hectares (95.54 acres) is reserved for tracks and wagon ways and 27.83 hectares (68.76 acres) is reserved for merchandise depots. The width of the quay is consequently, on the average, 43.96 meters (144.19 feet), of which 25.57 meters (83.87 feet) is for circulation and 18.39 meters (60.32 feet) for merchandise. If there is taken into consideration the same figures of the basins of the new port we find the following:

Basin water area of 98.88 hectares (244.24 acres); development of quay, 12,148.75 meters (39,847.90 feet). Quay surface for circulation, 33.579 hectares (82.94 acres); quay surface for merchandise, 25.52 hectares (63.0 acres); total, 59.1 hectares (145.98 acres). That is, per running meter of quay there is a water area of 81.40 square meters (876.98 square feet) and a quay surface per running meter of quay of 48.64 square meters (523.54 square feet), of which 27.64 square meters (297.50 square feet) is for circulation and 21 square meters (226.04 square feet) for merchandise.

In the Pinéde basin, now being built, the following are the figures: Water area, 26.945 hectares (66.56 acres); water area, per running meter of quay, 100.52 square meters (1,081.98 square feet); development of quay, 2,681 meters (8,793.68 feet); surface of quays, per running meter of quay, 74.42 square meters (801.04 square feet), of which 43.35 square meters (466.6 square feet) is for circulation and 31.07 square meters (334.44 square feet) for merchandise.

6. Relative Development of Railroad Tracks.

The total development outside of branch lines connecting with stations is, for the basins situated on the north side of the roadbed, 42.40 kilometers (26.29 miles). The length of quays served by the railroad is 7,024 meters (23,038.72 feet). The development of the railroad tracks per running meter of quay is 6.03 meters (19.78 feet). If there is now considered only the basin of the maritime station and the National basin, the development of railroad track is 24.60 kilometers (15.25 miles); the length of quay served, 3,525 meters (11,565.4 feet), and the length of tracks per running meter of quay served is 6.96 meters (22.83 feet).

In the case of tidal basins the *water areas of basins* per running meter of quay varies accordingly; that is, from 25 to 75 square meters (269.09 to 807.29 square feet). At Liverpool it is 37.4 square meters (402.56 square feet); at Antwerp, 62.7 square meters (674.89 square feet). In the case of open basins, where the ships maneuver with their own windlasses, it varies from 80 to 110 square meters (861 to 1,184 square feet). In a basin conveniently arranged it is about 100 square meters (1,076 square feet). The quay surface per running meter of available quay in tidal basins, as in basins opened freely to the maneuvering of vessels, oscillates between 45 and 75 square meters (484.37 and 807.29 square feet). At Antwerp it is about 60 square meters (646 square feet). With a width of 75 meters (246 feet), of which, on the average, 43 meters (141.04 feet) is for circulation and 32 meters (104.96 feet) for depots of merchandise, one has a very convenient quay. The development of railroad tracks necessary for serving the quay varies between 6 and 7 meters (19.68 and 22.96 feet) of running quay without counting connections.

7. Transit Sheds and Warehouses.

The author shows that it is difficult to fix upon the proper proportion of covered and uncovered areas for merchandise on account of the great variety of the merchandise. The capacity of the warehouse depends particularly upon the quantity of merchandise which has to be handled and the area, various other things being equal in proportion to the buildings themselves as to whether they have one or more stories.

At the port of Marseilles there are no warehouses except in the vicinity of the Joliette Dock. There is found in proximity to the port and in the city numerous warehouses, in which are placed merchandise intended for local industries. Consequently the relations existing between the areas of the warehouses and the port areas have no bearing upon what these would be in other ports. The author considers that a good plan of a port would have, say, a shed surface of 30 to 35 square meters (323 to 376.73 square feet) per running meter of quay. The warehouse should have a floor surface of from 50 to 60 square meters (538 to 646 square feet).

8. Relative Extent of Basins and Quays in Relation to the General Movement of the Port.

The author considers that the extent of the different parts of a port should be determined by the importance of the navigation and of the merchandise traffic imported and exported, as well as by their relative importance. Outside of special ports the relation between the weight

of merchandise imported and exported and the tonnage of vessels varies about as follows:

At Marseilles	0.56
Havre	.54
Barcelona	.60
Genoa	.51
Antwerp	.49
Dunkirk	.86
Rouen	.95

The question arises from the above, What would be the development of quays to suffice a given amount of maritime business? The author considers the question in a general way, and not in relation to the ports or basins which are devoted to special traffic. It has been admitted for a long time that the development of quays ought to be such that the tonnage of vessels arriving and clearing should not exceed 400 tons per annum per running meter of quay. The following is found at Liverpool: In 1890, 403 tons; in 1896, 406 tons; but it is exceeded in other ports. At Marseilles it is more than 800 tons, and in 1893 880 tons, which is double that at Liverpool, even, so that the water area of the basins reduced to running meter of quay in the port of Marseilles has a value of nearly double that of the Liverpool basins. If there is taken into consideration the traffic at Marseilles in one of the later years, 1895, e. g., it is seen that the net tonnage of the ships entering and clearing in the basins of the new ports was about 95,700 tons, which represents per running meter of 10,340 meters (33,915.20 feet) of available quays 870 tons, and it could have been still greater without inconveniencing the port.

The weight of merchandise, loaded and unloaded, in some basins was 4,989,313 tons, or, per running meter of quay, 482 tons, and per square meter of quay surface devoted to the storing of merchandise, 19.6 tons. The author gives other figures, some of which show that one of the leading steamship companies had a traffic of 1,028 tons per running meter of quay, and in 1885 attained 1,310 tons. From the many examples the author comes to the conclusion that the port will be in a good condition if the tonnages do not exceed the following figures: Eight hundred net tons for entrance and clearance and 500 tons of merchandise; 800 tons of merchandise per square meter of depot area. These figures take account of the ordinary variations of traffic, but there are ports where these variations attain extraordinary proportions, as at Galatz and Braila, the ports of the Danube, where the bulk of the traffic consists of cereals, which are shut up by ice during the last three months of the winter.

9. Lands Reserved for Commerce and Industry.

The facts that have already been given relate exclusively to the dimensions of the principal elements of a port. Outside of the water areas necessary for navigation and other areas, there is to be noted the fact that the surrounding land areas may be used for various commercial and industrial pursuits.

10. Conclusions.

As a general principle, outside of ports devoted to special traffic, the author gives the following:

1. When a port is established in such a way that vessels can conveniently and very rapidly effect their entrance and departure and their movements for coming alongside of quays, and when the quays are provided with the necessary apparatus for rapidly unloading and loading, there can be handled very easily and under good conditions, per running meter of quay per annum, a movement of merchandise of 500 tons and a navigation movement of 800 net tons, counting entrance and clearance.

2. The water area of basins and evolutions of operation ought to be 90 to 110 square meters (968 to 1,184 square feet) per running meter of quay.

3. The surface (terreplein) of quays containing the necessary space for storing merchandise and for circulating tracks and roadways ought to be calculated on the basis of 65 to 75 square meters (699.65 to 807.29 square feet) per running meter of quay, where the total surface of the basin and of quays is calculated on the basis of 0.31 square meter to 0.37 square meter (3.32 to 3.96 square feet) and averages 3.35 square meters (36.05 square feet) per ton of merchandise imported and exported.

4. The length of tracks necessary for serving the quays varies from 6 to 7 meters (19.68 to 22.96 feet) per running meter of quay served.

5. The quay areas reserved for circulation are 33 to 40 square meters (355.20 to 430 square feet); those for merchandise, 32 to 35 square meters (344.44 to 376.73 square feet).

6. The width to give to a bank quay ought to be about 70 meters (229.60 feet). It should be carried to 100 meters (328 feet) when warehouses have to be erected.

7. There ought to be given to the piers at least 100 meters (328 feet) of width, and to carry this width to 140 meters (459.20 feet) when warehouses have to be built. The transit sheds and the ground floor of warehouse occupy altogether a space of 50 to 60 meters (164 to 196.80 feet). The quays intended for serving warehoused merchandise ought to have, outside of the ground floor, 50 to 60 square

meters (538 to 645 square feet) of floors per running meter of quay. The uncovered areas of warehouses are calculated on the basis of 142 tons per square meter (13.2 tons per square foot); eight-tenths of a ton per square meter (.08 ton per square foot) for cellars and ground floors; seven-tenths of a ton per square meter (.07 ton per square foot) for the other stories.

8. It is not possible to establish relations between the areas of the water and the quays and the lands which can be utilized for commerce and industry.

The author shows on Plan I (No. 108) the arrangement of the Royal Victoria and Albert Docks, London, and of the port of Marseilles; on Plan II (No. 109), the arrangement of the docks at Leith, Liverpool, Tilbury Docks, London, and the new Basin Pinéde at Marseilles.

PAPER BY J. NYSSENS-HART, CONSULTING ENGINEER OF THE CITY OF BRUGES.

The relative importance of the different parts of a port depends essentially upon the kind of traffic of that port or on the kind and size of the ships which frequent it.

The greater and greater preponderance of steam navigation and the greater and greater progress made in the construction and propulsion of ships have greatly changed the methods of commerce. In 1872 the total number of sailing vessels was 56,767 and the tonnage 14,563,868, or a mean tonnage of 257; and there were at that date 4,335 steamers with a tonnage of 13,680,670, or a mean tonnage of 849. In 1897 we find the following figures: 29,315 sailing vessels, with a tonnage of 8,894,732, or an average tonnage of 303; 11,271 steamers, with a tonnage of 17,889,006, or an average mean gross tonnage of 1,587. The table from which these two extreme figures are taken indicates a rapid decrease of sailing vessels and a regular increase of steamers.

The sailing method of former times exposed the cargo and the passengers to all the caprices of nature. Steam, on the other hand, is least at the mercy of the elements; and the improvements made in its use have introduced into maritime transportation an important element formerly unknown—that is, regularity. The number of regular lines of steamers increases each year, and the maritime ports are obliged, under penalty of suffering decadence, to take close account of these changes in steam transportation.

The author divides steam navigation into express steamers, mixed steamers, and tramp steamers, and shows that the arrangements of a port ought to be made to suit each case.

1. Fast Lines.

The construction of steamers of greater and greater speed is the order of the day in all naval studies. At the last Congress of Maritime Navigation held at London, one special section was devoted to this subject. Since that time the Cunard Line and the North German Lloyd have put into service steamers of very great speed, the *Campania* and the *Lucania* and the *Kaiser Wilhelm der Grosse* and the *Kaiser Friedrich*. These ships reach speeds of 22 knots, and the works at Belfast are preparing the *Oceanic* with a speed of 25 knots (?). There exist only few ports where these ships can go, on account of their great draft of water.

These fast lines of great ships are concentrated at certain points in each port. For instance, at Southampton, in the Empress dock, which has 7½ hectares (18.53 acres) of surface and a quay development of nearly 1,100 meters (3,608 feet), with a 26-foot depth; it is in this dock that steamers of the American Line and the largest ships of the Royal Mail, of the Union Steamship Company, and those of the North German Lloyd, of the Hamburg-American Line, make their operations. This very modest quay development must consequently have a very considerable traffic, as these ships remain practically only a few hours in the port. The quays are all served by railroad tracks, by cranes, and sheds of very modest proportions otherwise, for these large ships carry very little merchandise.

These same principles have guided the projectors for the extension of the port of Havre, which is now in the course of construction. In this great French port the service for the trans-Atlantic steamers will be served by a quay of "call" in the anchorage, protected by a mole of 500 meters (1,640 feet) length. In Belgium, also, there will soon be a port situated on the coast for "call" by the rapid lines, and there is being built at this time at Heyst a shore port where a mole of nearly 2 kilometers (1.24 miles) of development will cover an anchorage, offering, under the protection of the mole, a quay length of 1,000 meters (3,280 feet), with 8 meters (26.24 feet) of water at low tide, a part of which will have 9.50 meters (31.16 feet).

2. Regular Mixed Lines.

This kind of a steamship increases in number constantly. These ships are arranged for passengers, but transport also an important cargo of merchandise. Their speed is about 16 to 17 knots. They serve the great routes of transportation to South America, Africa, India, and the extreme Orient, and constitute a very large proportion of the business of the ports of northern Europe. These ships require special advantages in the way of handling very large cargoes quickly, which is generally a mixed cargo. The regularity of their movement is not as essential as that of the passenger lines. It is necessary that

the goods should be placed in security under the protection of the sheds, and the dimensions of these sheds will vary with the importance of the traffic which the line has in any good port, but it is generally conceded at the present time that these sheds should be sufficient to contain the entire cargo of the ship.

This principle has been carried out notably at Rotterdam, where, at the quay of South Rhynhaven, the sheds have up to 40 meters (131.20 feet) of width. These sheds ought to be served by railroad tracks in sufficient number to allow for the arrival and departure of merchandise without interrupting the operation of unloading and loading the ship. It also ought to be conveniently arranged for them to be accessible to drays, and also so that the ship can load directly or unload directly upon or from the cars.

The ships of these regular lines which form a large part of the general maritime traffic demand direct attachment to the quays. This consideration is particularly important for all the large interior ports of the north of Europe situated along rivers. The first element of this condition is found, then, in the accessibility, and the most perfect possible, of the port and the quay.

In rivers where the régime of the tide gives constantly varying anchorages, and where sometimes there are fogs and at other times ice, and constantly changing channels of the river, there are great obstacles in handling the business. It is necessary, therefore, to cause to disappear as much as possible the various obstacles which nature has placed in the way. The regularization and deepening of tidal rivers appears to be, then, one of the principal things required for the prosperity of a port. The artificial opening of a new waterway to Rotterdam by the sea constitutes without doubt one of the most important elements of its increasing greatness. Hamburg is deepening the now too shoal passageways of little depth, and Bremen has realized in this direction a solution, of which the results, even exceeding the predictions, have given to hydraulic science a great encouragement. The Scheldt between Antwerp and the sea is susceptible of work of the same kind, which should be gone at in some definite way to secure the most perfect conditions of navigability. In other places the access to the rivers is barred by their embrochures.

The dredging of the bar of Charpentier on the lower Loire and those at the mouth of the Mersey have shown that the science of the engineer and his methods of action can successfully combat this kind of obstruction also. This question of good navigability of access has been settled in various ways. New York has deepened its channel through the Gedney channel and the main channel; Liverpool by the works of the Queens channel; Nantes by the dredging of the Charpentier bar; Rotterdam by the new waterway, and Bremen by the complete and systematic correction of the entire Weser.

The author then enters upon the discussion of the relative surface of basins, quays, etc., and gives many examples, but as these have been given in detail in the paper by Mr. Guérard, it is unnecessary to go into further details.

The author then takes up the irregular or tramp steamers and sailing vessels not requiring to be placed always at the quays, but to be served by anchored buoys placed in basins of considerable dimensions, where the boats from the interior can circulate freely around the maritime vessels. He gives a résumé of his paper as follows:

The traffic of the regular and rapid lines demand direct quay work where a short length of quay is susceptible of doing very important business; not very large sheds, but perfect connections with important railroad lines for passengers, postal and express matter, and arrangements for loading and unloading with great rapidity. The regular semirapid steamers carrying cargo and passengers require a great development of quays, large sheds served by railroads and roadways, and accessible on one side to the lighters, and basins of reduced width and without locks. Irregular and tramp steamers require basins like the above, even more reduced in size of quay surface, and railroad lines less numerous. Sailing vessels require great basins with surfaces accessible to flotillas of lighters, and when they discharge at a quay, the same installations as the irregular steamers.

FOURTH SECTION.

Third question.—Free ports; reasons therefor and conditions of establishment, installations, and dimensions.

PAPER BY MR. A. CHARGUÉRAUD, OF PARIS.

PREAMBLE.

There are at present no free ports in France. There are such in other countries, notably at Hamburg, Bremen, Lubeck, Copenhagen, Gibraltar, Genoa, Trieste, Malta, Singapore, and Hongkong.

The author leaves the engineers of those countries to discuss the methods of operating in their ports. His paper is divided into two parts:

1. The general consideration of the question of free ports.
2. A historical summary of these ports in France.

He briefly discusses the relations of these ports to the two methods of importation of goods, either by free trade or protection.

A country has free trade or protection according to the customs laws, but in either case modification of the general laws are necessary.

The protectionist régime has always been accompanied by indispensable correctives. The method itself rests upon the principle that a great country ought to be sufficient to itself, particularly in respect to all products of prime necessity, in order that it might not be deprived of them in any emergency. To accomplish this purpose it becomes necessary to prevent the introduction into such a country of foreign products which might come into competition in the markets with the national products. In such cases there is an actual prohibition, and in order to render it so the protecting duties are made very high. But, on the other hand, there are products which a country does not produce in sufficient quantity for its necessities, and even some products that it does not produce at all. In that case it is necessary to open the door. Sometimes the duties are maintained by a desire to maintain the cost in order to favor the production of some products, instead of relying upon foreign products of the same class. Whatever the customs rules or regulations may be, it is indispensable that the products from foreign countries should not be subjected to inconvenient methods of handling and of distribution in the country to which they are sent.

For the purpose of removing as much as possible the hindrance to the easy movement of commerce there have been established bonded warehouses, which are simply places where goods can be protected and be temporarily placed, although subjected to the duties. During the time in which they remain in the bonded warehouse they are considered to be without a country as far as relates to the collection of duties. When they leave the bonded warehouse they then are subject to the payment of the duty.

There are two kinds of bonded warehouses—one real and the other fictitious. The real bonded warehouse can exist only in the localities for which a concession has been made. It is placed in a building by itself, isolated from all other construction and by approval of the administration and all movements in and out are under the customs administration. It is necessary to arrange in the building for offices and sleeping rooms for the government agents to whom is intrusted the care of the building.

The bonded warehouse called "fictitious" (fictif) is essentially maritime and consists of private warehouses. There is not admitted into such warehouses only merchandise upon which a limited duty is placed. In the bonded warehouse of the fictitious class there can only be made the necessary manipulations for preventing the deterioration of the merchandise. This can only be done by authorization of the administration which has it in charge.

In a real bonded warehouse an authorization can be made for certain changes in goods, to be done in the presence of a Government

agent, such as rebaling and dividing or combining packages, and often to make certain mixtures. A bonded warehouse is only useful for those goods which have to be reexported in their first general shape; that is, the goods can not be worked into other products. There is, however, often arranged what is called a place for "temporary admission" of goods, where they can remain a certain time, and under certain special requirements be transformed into other shapes.

The author then goes into some considerable detail in order to show the various methods by which this can be done, and the various rules and regulations for the work. He does not believe that, in France at least, the institution of a free port would perform the service which would be expected of it.

He divides free ports into two categories, those which, like bonded warehouses, are intended to receive only such merchandise as is not to be changed by manual labor, or to have the real essence of the goods changed. Such a case as this exists at Genoa in the "Deposito franco," and the others, which enjoy the privilege of temporary admission, contain workshops and manufactories. The raw products are there handled and transformed and put into entirely different shape; an illustration of such a port is Copenhagen.

The author, however, does not believe that such a method can be employed in France, for the reason that there are many special tariffs due to the different relations of French colonies, such as Corsica and Algeria, where there are special customs, taxes, and duties; also, on account of the octroi duty upon the admission of goods into France and into various parts of France. He thinks that it would be necessary for the laws in France to be greatly changed to permit the creation of free ports.

In the historical summary which the author gives he shows that formerly there existed in France certain ports, and even cities, that had special privileges in the introduction of goods. Since the fourth century, and during the Middle Ages, the city of Marseilles was practically a free city, and by an ordinance in the eighteenth century the same privileges were granted to Dunkerque, Lorient, Bayonne, and St. Jean de Luz. The author gives the details of the laws under which these cities were established as free cities. The present custom laws, by which these extensive privileges were taken from these cities, were passed in 1803; although the law in respect to Marseilles was not changed until 1817, which finally and definitely took away the franchise which this city had held for so long, and substituted for it the bonded-warehouse principle. Since that date (1817) the question of free ports in France has not been taken under consideration, and it is only recently that the question has been again taken up to be exam ined into.

FOURTH SECTION.

Fourth question.—Single lock gates; machinery recently devised.

PAPER BY M. CHARLES PIENS, OF BRUGES, UPON THE GATES OF THE LOCK OF THE NEW MARITIME CANAL AT BRUGES.

GENERAL ARRANGEMENT OF THE LOCK AND THE GATES.

The construction of a port of call on the north seacoast at Zeebrugge (Heyst), for the port of Bruges, and for a canal connecting these two ports, was contracted for by the Belgian Government with Messrs. Louis Coiseau (a Parisian engineer) and Jean Cousin (a Brussels engineer) by virtue of an act of Government of June 1, 1894. These works are now in process of construction.

The port at the coast comprises an anchorage protected by a curved mole or jetty, connected with the sand dunes of the shore and extending into the sea to a depth of 8 meters (26.24 feet), with a quay for vessels and a terreplein, a canal and a maritime lock connecting the protected anchorage with the canal, which extends to Bruges. The lock is in the entrance channel, 750 meters (2,460 feet) from the low-water line of the shore. It has two heads and an intermediary basin; the heads are 62 meters (203.36 feet) long and the basin is 158 meters (518.24 feet); that is, 282 meters (925.19 feet) is the total length of the work. The lock has 20 meters (65.60 feet) opening. The sills are 5.50 meters (18.04 feet) below the level of mean low water of spring tides. The useful length of the lock is 256 meters (839.89 feet). This great useful length is accomplished by a special plan of gates. Each of the heads of the lock has only one gate, and each gate has only one leaf, so that entire command of the operations is obtained by two leaves. The gates are rolling gates; they open and shut the opening of the lock normally to its axis. When the lock is opened the gate is run back into a chamber which is built in the return wall of the lock; when the opening is closed the gate rests on a sill, and it is so arranged that it can act at will as a flood or an ebb gate. These rolling gates have several novelties and marked advantages.

FLUCTUATIONS OF THE WATER LEVELS.

The extreme range in the difference of level will be from −0.70 meter to +4.50 meters (−2.29 to +14.76 feet).

DESCRIPTION OF THE GATE.

The author goes into a detailed description, and operation as well; but, as all the details are clearly shown on the Plans I and II (Nos. 113 and 114), it is unnecessary to give more than a general résumé of the descriptive features.

Each gate is formed of a metallic caisson of 4.50 meters (14.76 feet), of uniform thickness, having in elevation the figure of a trapezoid of which the short side is 20.71 meters (67.94 feet) long and the large side 24.49 meters (80.33 feet) long. The height of the caisson or gate is 12.70 meters (41.65 feet). The lower edge reaches down to elevation −5.90 meters (19.35 feet), and the upper surface is leveled off at +6.80 meters (22.30 feet), or 0.20 meter (0.65 foot) above the highest tides.

The caisson is divided into two parts by a horizontal floor or bridge, which is placed at elevation −1.05 meters (3.44 feet); that is, 0.35 meter (1.15 feet) below the lowest tides. This bridge, with the parts below it, constitutes a compartment which is entirely water-tight, and which holds the necessary ballast to prevent the gate from rising. Under the fluctuations of the water level the volume of water displaced by the gate does not vary greatly. The load on the wheels remains practically invariable, and that can be regulated at will by means of ballast. The gate is supported on two axles and by eight wheels each 1 meter (3.28 feet) in diameter. The track on which the gate rolls is formed of two Goliath rails. At the lower part, where the wheels are, are arranged two chambers 2.30 meters (7.54 feet) wide, taking in the whole width of the gate. Access is had to these chambers by means of cylinders 0.70 meter (2.29 feet) in diameter, arranged with an air chamber, so that the wheels and their bearings can be examined at any time. It is only necessary to eject the water by compressed air for examinations. Five openings with gates 1 by 0.70 meter (3.28 by 2.29 feet) are arranged in the side of the gate for the purpose of letting in water for flushing purposes. On the sides of the masonry recesses are timbers of greenheart about 1 foot in width, their purpose being to assure absolute dryness at contact with the central parts of the gate.

The volume of water displaced by the dry chamber above described is 418 cubic meters, or 429 tons. The gate proper weighs 200 tons and the ballast 279 tons. An excess of weight of 50 tons assures the stability of the gate during its movements.

THE PRINCIPAL ELEMENTS OF THE GATE.

The general framework comprises eight large vertical frames, placed at intervals of 2.50 meters (8.20 feet), extending through the whole height of the gate and across its entire width. The vertical sides of these frames constitute the ribs for the edges. They are formed of U-irons. The horizontal bars of these frames are composed of two irons of similar form. The vertical frames are connected by six crosses of horizontal connection, spaced unequally, according to the amount of the pressures. These cross frames are made of beams

of double T-iron of 0.35 meter (1.15 feet) in height, composed of a central part of 8 millimeters (0.32 inch). The belts on the sides of the caisson are riveted on side strips of the large vertical truss, and on the ribs the thickness varies from 7 to 10 millimeters (0.28 to 0.40 inch).

CONDITIONS OF RESISTANCE OF THE PRINCIPAL ELEMENTS.

The gates are of steel. They have to resist and meet the conditions caused by both the flood and the ebb tide.

CONDITIONS OF EQUILIBRIUM OF THE GATE.

As has been stated, there is an exclusive weight of 50 tons when the gate is submerged. The horizontal section of the upper chamber is of such size that a difference of level of 0.50 meter (1.64 feet) above will suffice to equilibrate this excess of weight and to make the gate float.

The author goes into great detail in order to show that the various valves and other arrangements assure the equilibrium of force brought against the gate at different stages of the tide.

ARRANGEMENT OF THE CHAMBER OF THE GATE.

This is shown on Plan II (No. 114). When the lock is open for navigation, the gate is placed laterally in the chamber of refuge in the wall of the lock. The bottom of this chamber is 0.80 meter (2.62 feet) in the foundation.

POWER REQUIRED FOR MANEUVERING THE GATE.

These are so arranged that they are sufficient to open the gate in three minutes. The necessary effort for overcoming the various resistances to the movement is estimated at 7,000 kilograms (15,435 pounds); 1,000 kilograms (2,205 pounds) for the rolling resistance and 6,000 kilograms (13,230 pounds) for the water resistance.

THE MECHANISM.

This is entirely electrical. The windlass which performs the work is actuated by a dynamo which can furnish 20,000 watts on the shaft.

In case of an accident the gate can be moved by hand, requiring about fifteen minutes by three men using levers.

MOTIVE POWER EMPLOYED.

The installation of a port at the coast comprises electric installations intended to furnish the necessary power for maneuvering the gates, bridges, capstans of the maritime lock, as well as the cranes installed on

the jetty in the sea, and to light the port in all its parts, and, finally, to operate the tools in the repair shop. The electric installations are double. Each of them consists of a compound steam engine of the Willans type, with four cylinders acting directly upon the shaft of a generating dynamo with a continuous current. Each machine can furnish a current of 350 amperes, with 440 volts.

GENERAL CONSIDERATIONS.

For several years there has been shown a tendency to substitute single gates for double gates for canals.

As early as 1882, M. le Baron Quinette de Rochemont arranged for turning gates with one lift, for his type of lock of the canal projected from the Scheldt to the Meuse. This lock was adopted by the French administration, and is described in a memoir by M. de Rochemont, in 1883, in the Annales des Ponts et Chaussées.

In reference to maritime navigation, caissons forming a single gate have been in use for some time, particularly in dry docks. Gates with one leaf, for maritime locks, have been very extensively used. There is a turning gate of this kind at Bristol and one at Dundee, which have been in use for some years. This kind of a gate has been installed recently in France on special plans. In 1887 it was applied particularly to maritime locks on the Havre and Tancarville Canal. These gates were also turning gates. (See Memoir of M. Widmer, Annales des Ponts et Chaussées, 1892.)

Gates with one leaf, which are moved like the one at Bristol, are very exceptional. They have been employed to isolate two flood basins, the connecting channel of which is shut by a sliding or rolling caisson. At Portsmouth it is a sliding caisson. But the works of the port of call at Bruges, according to the author's knowledge, constitute the first application of a rolling gate to a maritime lock.

The author then shows the advantage of a single gate like this over the uncertainties in movement of a double gate, such as is usually employed.

PAPER BY R. P. J. TUTEIN-NOLTHENIUS, OF ZUTPHEN, HOLLAND.

This paper describes a single lock located at Andel, Holland. This was simply a project when the congress met at The Hague in 1894, and a brief description of it was offered to the members who took part in an excursion to the Holland Diep. The lock is situated near the confluence of the Belgian and French Meuse and the Wahal, the principal arm of the Rhine, not far from Woudrichem and Loevestein. The object of the lock is to prevent the boats from passing from one

river to the other when the course of the Meuse is obstructed at Andel. These two rivers are tidal rivers; consequently it was necessary to have tidal locks at either end to take care of the rise and fall of the tide.

The gates at the lock differ from other gates of the same kind by utilizing a triangular space provided, which gives the gates the form of a fan.

The author describes in very full detail the plan, and refers to an accompanying sketch, which shows not only the general location of the lock, but also the details of nearly all parts of the gates, even details of the mechanisms, and shows also the materials of which these parts and mechanisms are composed. (See No. 115.)

CHAPTER VI.

FIFTH SECTION.—Tolls.

First question.—Maritime tolls and local rates; method of collection; collection per ton capacity or per ton of weight; character and amount of local rates.

PAPER BY A. CHARGUÉRAUD, OF PARIS.

The Object of the Paper.

The chief of the division of navigation of the ministry of public works, M. Beaurin-Gressier, who had intended to write this paper, was unable to do so and intrusted it to the author. However, the latter has drawn largely from certain facts furnished by the former and from some matter published by the former.

In the first place, the author proposes to give several definitions and to indicate the principles which ought, in his opinion, to rule in the matter of tolls and of fiscal taxes.

In the second place, he will treat of the theoretical considerations, and, in the third place, he will give a historical summary of maritime taxes in France, to be followed by a recapitulation, with some observations.

First part.—*Definitions and general principles.*

The principles are, after some discussion, all particularly stated in an extract from M. Beaurin-Gressier's paper to the Fifth Congress of Inland Navigation, in which the main idea is that the payment of taxes should bear only upon those who reap a profit from the operations of a port, and that the taxes should be employed exclusively for covering the expenses of the operations of a port.

Second part.—*Theoretical considerations.*

These are also extracted from the paper above mentioned. The first point to determine is the choice of the basis of the tolls. The author then goes into a general discussion to ascertain this basis, referring to the parts played by ports in general commerce, and comparing them to railroad freight stations, which are only used for the transfer from the railroad to other means of transportation by river or sea, or to go into

the interior by other railroads and by wagons. A port simply plays the same part. That which seems to receive the greatest profit is the ship itself, consequently tolls should be placed upon it, and its detention in the port should require a remuneration to the owners of the port.

NATURE OF THE SERVICES RENDERED.

The first point to establish is the nature of the services rendered to the ships in the port. A ship is a complex object of variable dimensions, presenting a great diversity of forms and of means of action. It is itself an instrument able to perform extremely variable purposes; it serves as a transport for persons, merchandise, express, and mail; it comes from far or from near; it remains in the port for a considerable time, or it only touches it; it accomplishes all of its operations at one time, or performs only a partial operation at a certain port; it goes regularly or irregularly.

THE FIRST SYSTEM OF TOLLS.

In the first system it should be observed that the service rendered by the port to the ship is in the direct relations to the dimensions of that ship. Whether loaded or unloaded, it occupies about the same space, and in about the same way interferes with the operations in the port, and the cost of calculation of the tolls and other work is practically the same. For these reasons the port charges are put upon the ship.

SECOND SYSTEM.

In this system the port charges are placed upon the cargo, for the reason that it ought to support entirely all of the costs.

There are various characteristic circumstances and conditions in the operation made in a port, and other important questions to be considered in placing the port charges upon the ship or cargo. There is the general mass of cargo to be transported, and the distance it has to be carried in the port from the ship to the warehouse, or for transfer to rail or inland navigation. Then there are different kinds of goods to be handled—passengers, animals, objects of various kinds—and to be handled in different ways. In the ship various kinds of cargo occupy different spaces.

THE ESSENTIAL ELEMENTS OF THE BASIS FOR CHARGES.

All these various subjects above mentioned ought to be combined and considered under their various forms, in order establish a basis of charges. The author summarizes these various features as follows:

1. The dimensions of the ship characterized by its volume, its length, or by its draft.

2. The importance of the cargo and the method of checking it, either per head, or by weight, or by volume, or by packages or pieces.

3. The time of detention in the port.

4. The distance to which it is necessary for the ship to go with its cargo, or the distance from which it has come.

5. Whether it is a sailing vessel or a steamer.

6. The special purpose or kind of cargo of the ship.

THE AMOUNT OF THESE TAXES OR TOLLS—THE OBJECT OF THE TOLL.

The first consideration to meet is evidently the amount required to cover the expenses for which the tolls are collected.

FLEXIBILITY OF THE TAXES OR TOLLS.

These should be arranged on the principles above outlined, due to the various kinds of vessels and the various kinds of service which they render.

THE INFLUENCE OF COMPETITION.

This has to be considered for it is exercised in a thousand different ways, and many considerations have to be taken into account.

Between two points on the same shore of the same continent one can take an interior route, either by canals or rivers or railroads, or even by different maritime routes, or these various routes can be combined in moving freight from one point to another. Between two separate continents the points of entrance and clearance offer a great variety, and there are different means of transportation over the same lines.

MEASURES THAT MAY BE TAKEN AGAINST ENCUMBERING THE PORT.

The port charges should be graduated in such a way as to make the stay of the ship in the port as short as possible, in order not to interfere with other vessels.

THIRD PART.—*Historical summary of maritime taxes and port charges in France.*

FOURTH PART.

The details of the third part are summarized in a recapitulation as follows:

Under the old régime specialized taxes and tolls were very numerous. Between 1793 and 1802 they disappeared completely to give place to a general tendency. From 1802 to 1814 there was a specialization, but which worked badly and was done away with. From 1814 to 1825 there was a fiscal tax only. From 1825 to 1860 there existed

a régime of specialization and establishment of port charges, which permitted the entire suppression of fiscal taxes. From 1866 to 1872 the port charges were alone in existence, but they related entirely to the tonnage of ships. From 1872 to 1893 the same general rule existed with some modification. From 1893 to 1897 the same system was maintained, but there was given to the port charges a much greater elasticity following local conditions. The fiscal tax is preserved in all its rigor.

Since 1897 the fiscal tax is sensibly modified. The tonnage of ships remains one of the principal elements of valuation; but the quantity of merchandise handled becomes the basis for taxation.

PAPER BY A. FLAMANT, OF ALGIERS.

This paper is devoted entirely to a description of the methods prevailing at the ports of the French colony of Algeria.

Without going into the details of the depths of the important harbors, the tonnage of the ports, and the methods of handling the freight, whether upon quays directly or by lighters to the shore, it will be sufficient to give in tabular form a summary of the various port charges at four of the principal ports of Algeria. The table gives in decimals of a franc the port charges per ton of 1,000 kilograms (2,205 pounds).

	Quay.		Sanitary and passport.		Pilotage.		Total.	
	Franc.	Cents.	Franc.	Cent.	Franc.	Cents.	Franc.	Cents.
At Algiers, about	0.15	2.89	0.03	0.58	0.09	1.74	0.27	5.21
At Oran, about	.14	2.7	.05	.96	.08	1.54	.27	5.21
At Bone, about	.05	.96	.03	.58	.05	.96	.13	2.50
At Philippeville	.07	1.35	.02	.38	.13	2.50	.22	4.25

The recent legislation, which was enacted the 23d of December, 1897, diminishes considerably the quay charges.

PAPER BY M. HERTOGS OF ANTWERP.

This short but very vigorous paper by the author combats the whole system of port charges, and he gives very strong reasons, from experience at Antwerp, why they should be abolished altogether. He states that experience in Belgium demonstrated, without question, that, in view of the prosperity of ports, all taxes upon navigation, without any exception, should be abolished. The general trend of his reasons for this is that all the ports require the navigation for their own prosperity and development, and no laws placing restrictions in the way

of port costs upon navigation should be permitted, and no pilotage, and, for the same reason, no light-house duties. He states that the ports, being a work of Nature, are a gift to humanity.

They are scattered about the globe in various countries, and, that being so, it is the part of the various countries and ports to perfect and complete the work which Nature has given to them for the benefit of mankind. The carrying out of this principle, he believes, will redound to the prosperity of any port that adopts it.

There should be entire liberty to navigation in all ports, and there should be no repressive laws.

He attributes the extraordinary growth of the port of Antwerp to the gradual abolition of port charges.

FIFTH SECTION.

Second question.—Unification of the system of measurement of inland navigation boats; present condition of the question.

PAPER BY A. SCHROMM, OF VIENNA.

This subject is of little interest to readers in the United States for the reason that it treats of the introduction of sizes of boats that will be sufficiently uniform to pass from one country to another, and through canals of the same class which connect one European country with another.

One question discussed in the paper is whether the cubic measurement of a vessel should be taken as the proper basis of measurement, or whether the displacement weight of the boat and its cargo should be used for that purpose.

The author goes into a very detailed discussion to form his conclusions, which are as follows:

CONCLUSIONS.

The capacity of boats of inland navigation ought to be expressed in weight tons, and the authorized immersion of a boat—that is, the line of load flotation—can not be expressed uniformly for all navigable waterways. This point ought to be established according to the method of construction of the boats and the conditions of navigability in each water course.

For boats very solidly built or very little subject to deformation by the load upon the French, Belgian, and Netherlands canals, as well as for iron boats, it is convenient to adopt the basis of volume of water displaced, but not for boats subject to deformation by their load, which occurs on the Elbe, Oder, Vistula, and the Danube.

PAPER BY M. DEROME, OF COMPIÈGNE, FRANCE.

The author discusses the present state of the question so far as it concerns the network of navigable waterways of France, Belgium, Germany, and Holland, showing the difference between the different countries, and discussing the reforms that ought to be adopted to obtain a unification of methods.

He gives a history of the International Conference at Brussels in 1896, which was called by the initiation of the Belgian Government. The four countries above mentioned signed an agreement on the 4th of February, 1898, based on the conclusions of that conference.

The author discusses the various articles of that conference, and finally gives in an appendix the articles of agreement and the special rules which explain the general articles.

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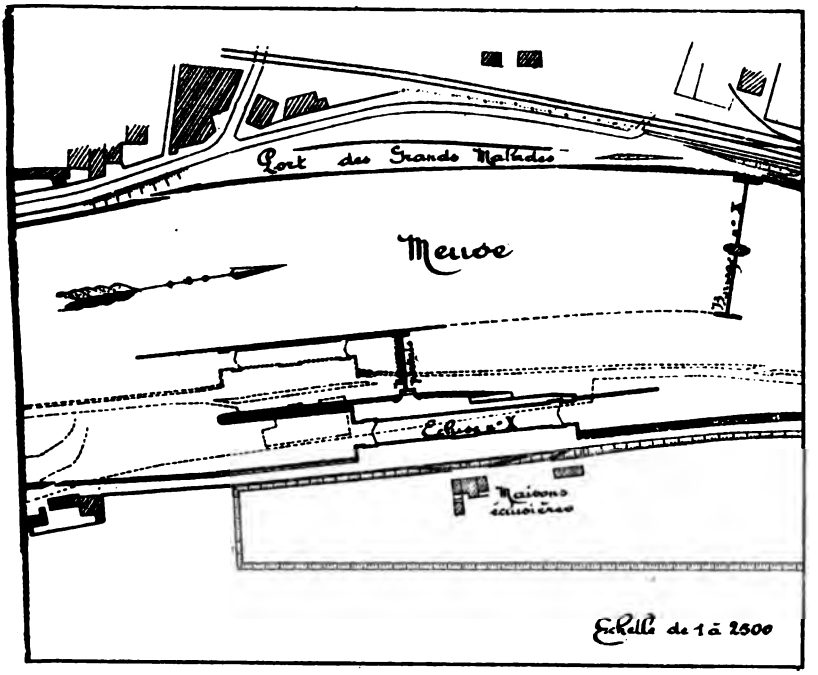

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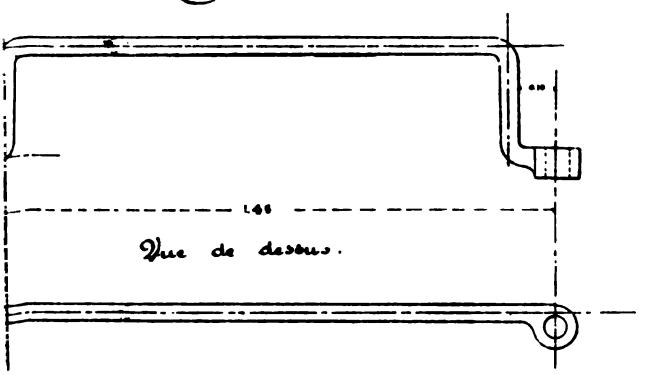

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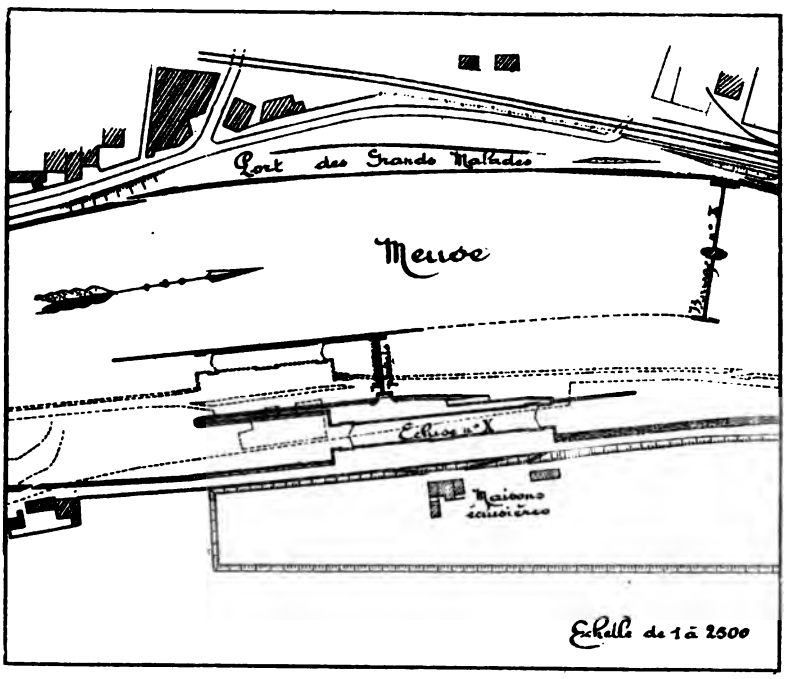

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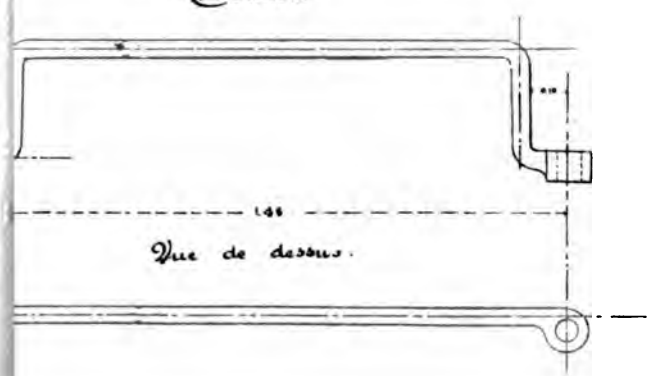

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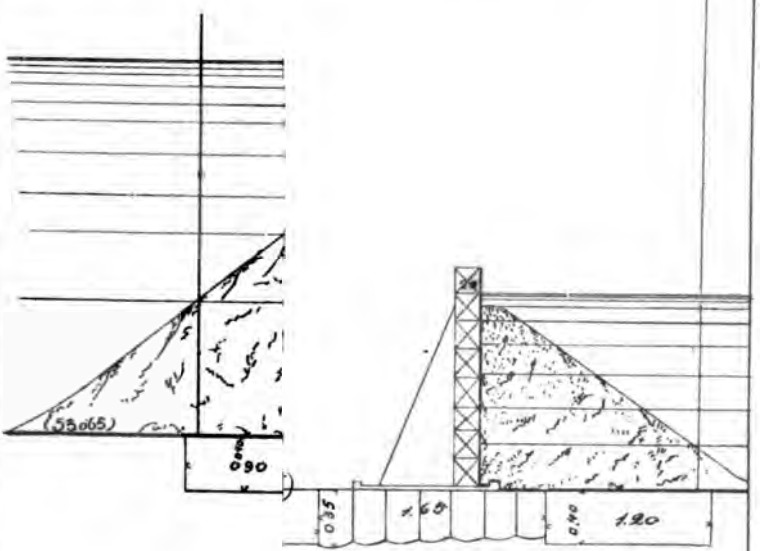

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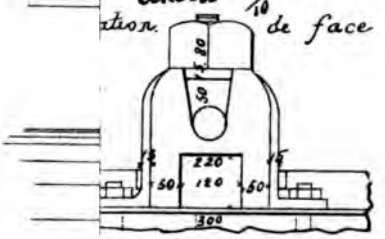

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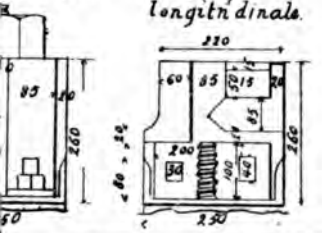

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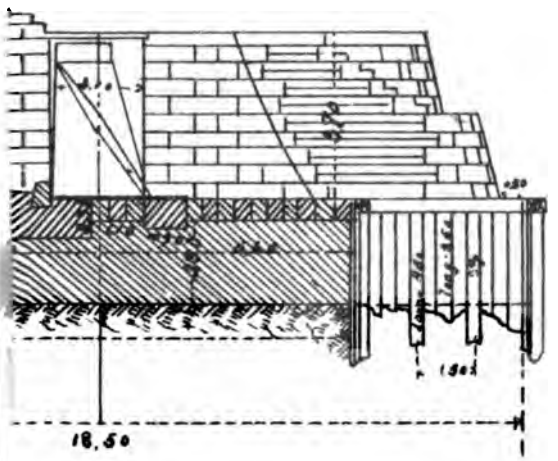

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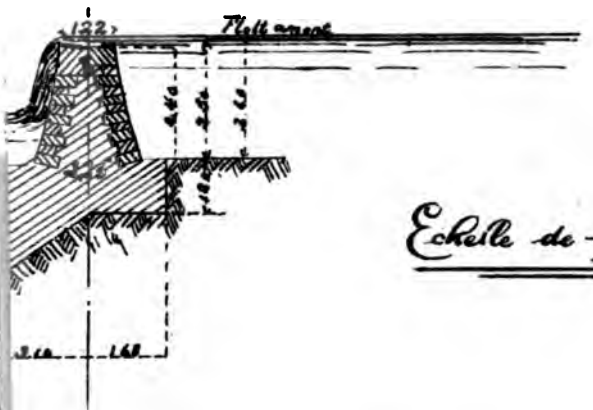

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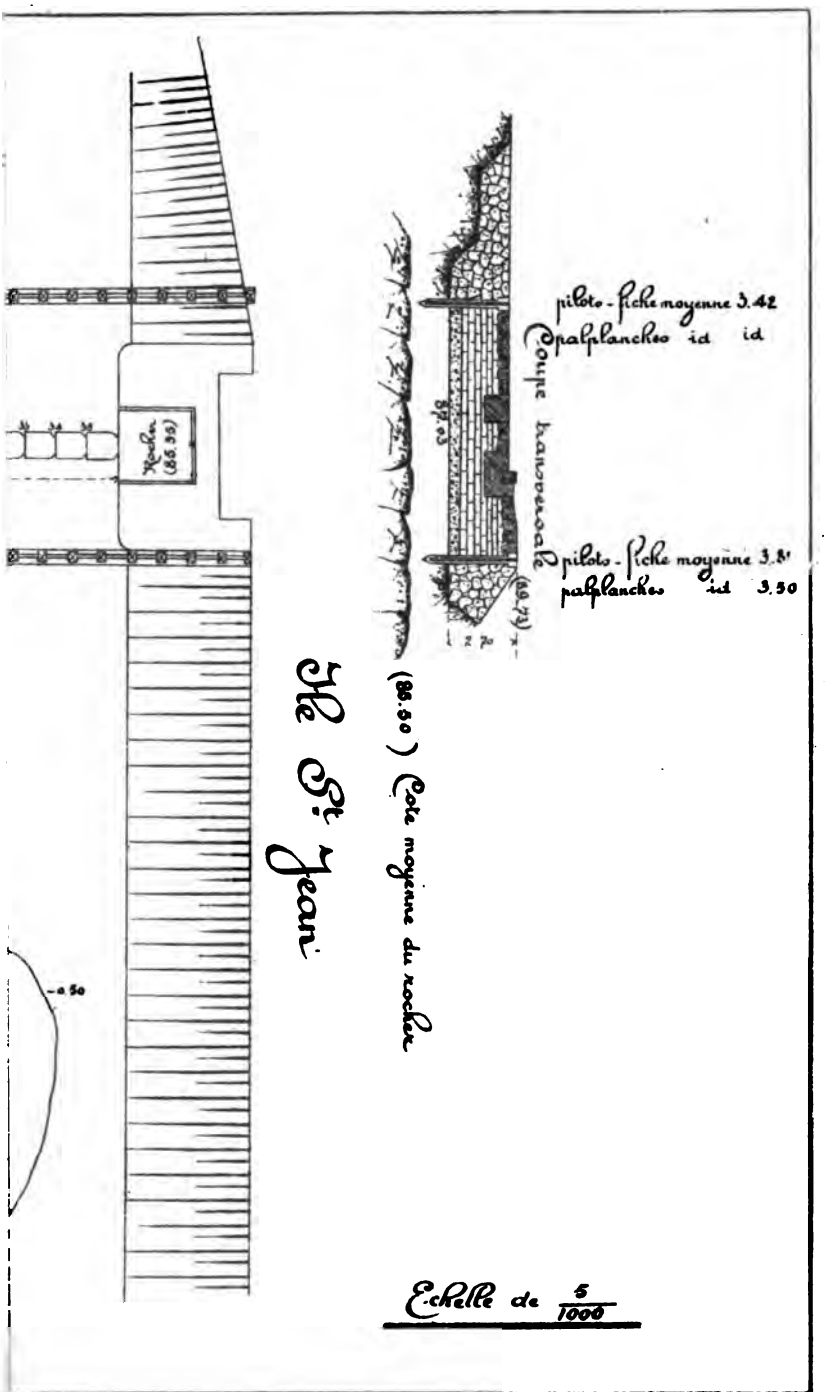
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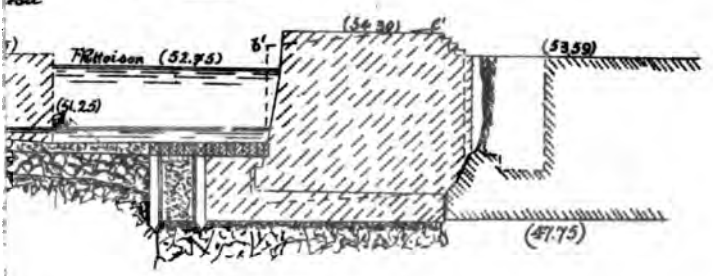

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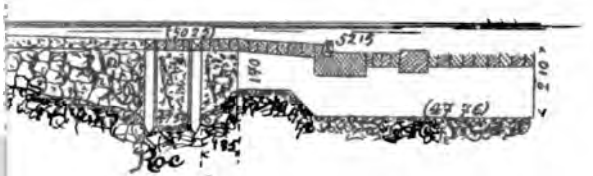

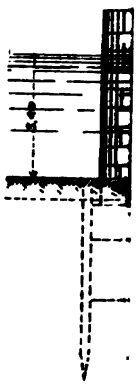

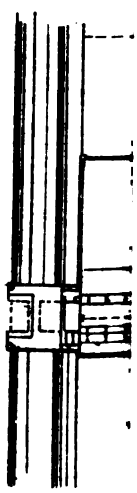

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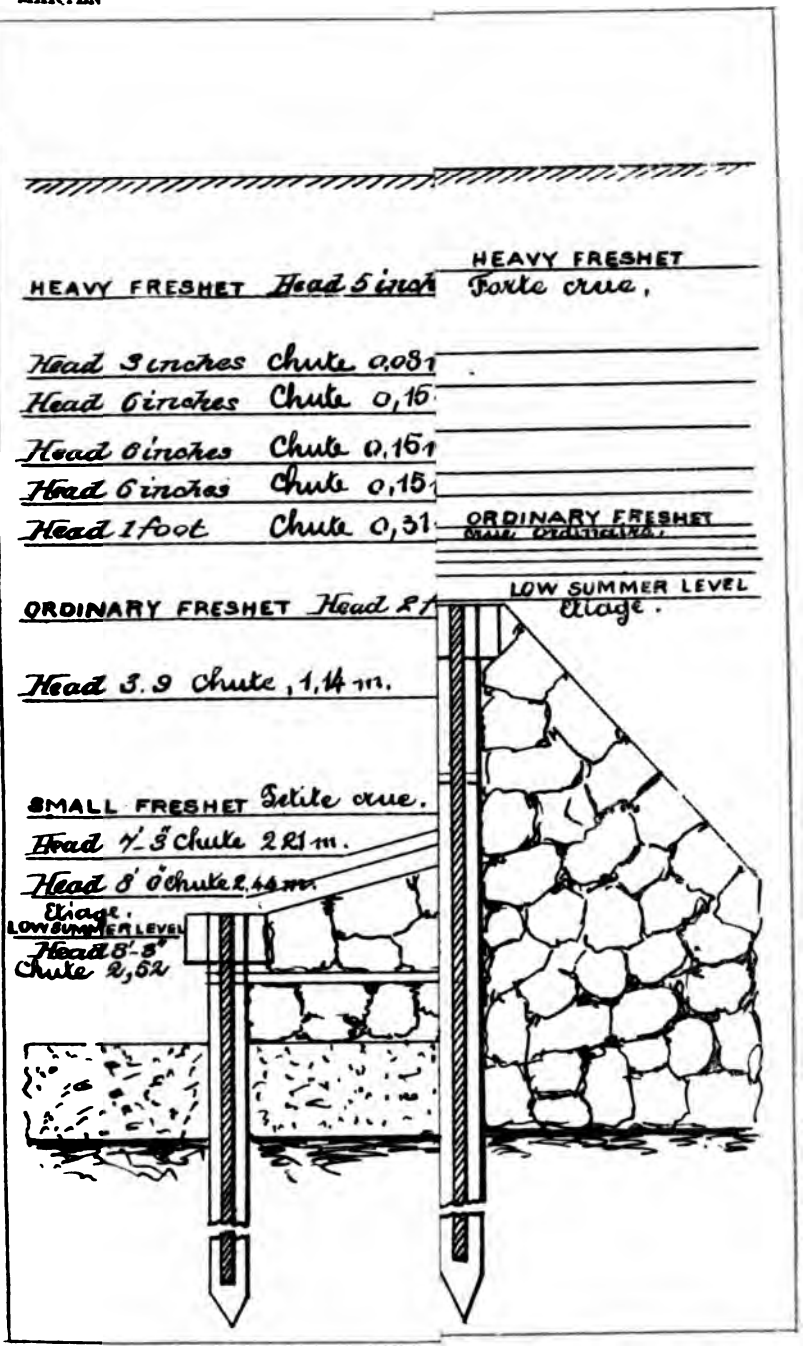
HEAVY FRESHET Head 5 inch
HEAVY FRESHET Forte crue.
Head 3 inches Chute 0,081
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Head 6 inches Chute 0,15
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ORDINARY FRESHET Head 2 f
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Head 3.9 Chute, 1,14 m.
SMALL FRESHET Petite crue.
Head 4' 3" Chute 2,21 m.
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Head 8'-8"
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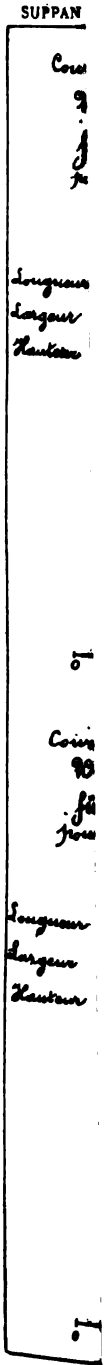
SUPPAN
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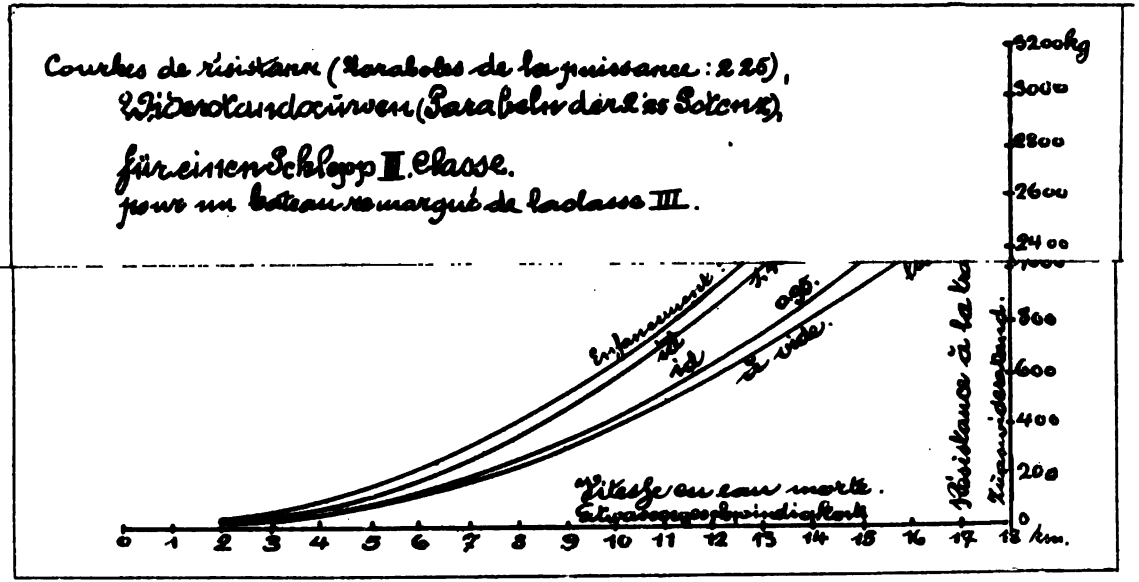
ÜBER DEN WIDERSTAND DER SCHIFFE GEGEN DEN ZUG Blatt III.

SUPPAN **RÉSISTANCE AU MOUVEMENT DES BATEAUX** Planche III.



VII. INTERNATIONALER SCHIFFAHRTS-CONGRESS. ERSTE ABTEILUNG. — 4ª FRAGE.

VIIe CONGRÈS INTERNATIONAL DE NAVIGATION. PREMIÈRE SECTION. — 4e QUESTION.

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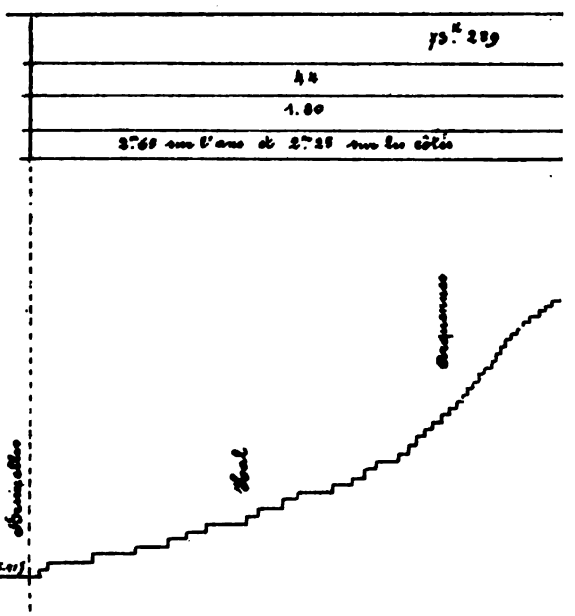
No. 13

E. CHENU

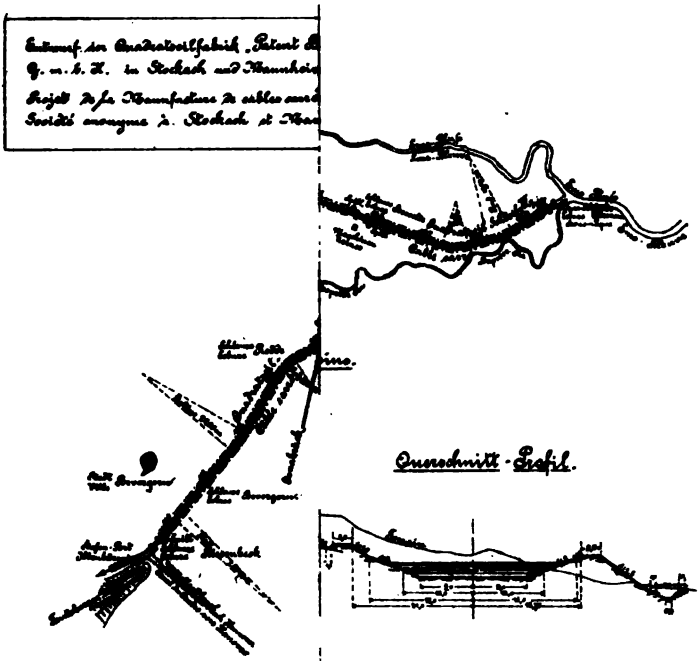
Bruxelles

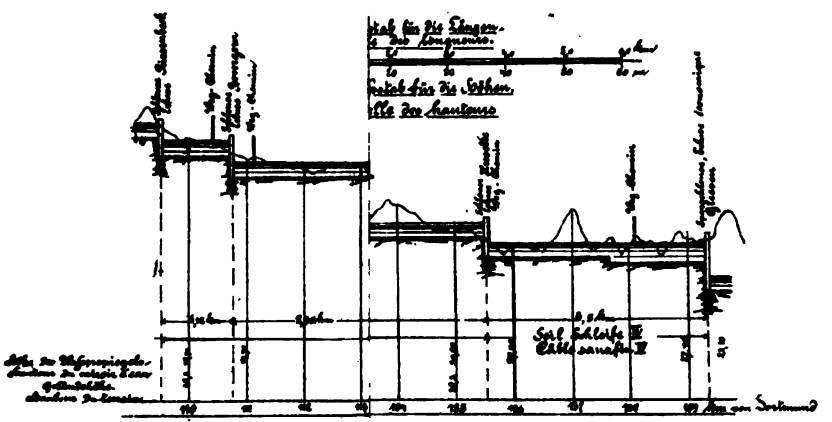

75.ᵏ 239
44
1.80
3.ᵐ69 sur l'axe et 2.ᵐ28 sur les côtés
Bruxelles
Hal
Braine-le-Comte

N° 17

Canal Dortmund-Emshäfen

Section: Ricenbeck Gleesen.





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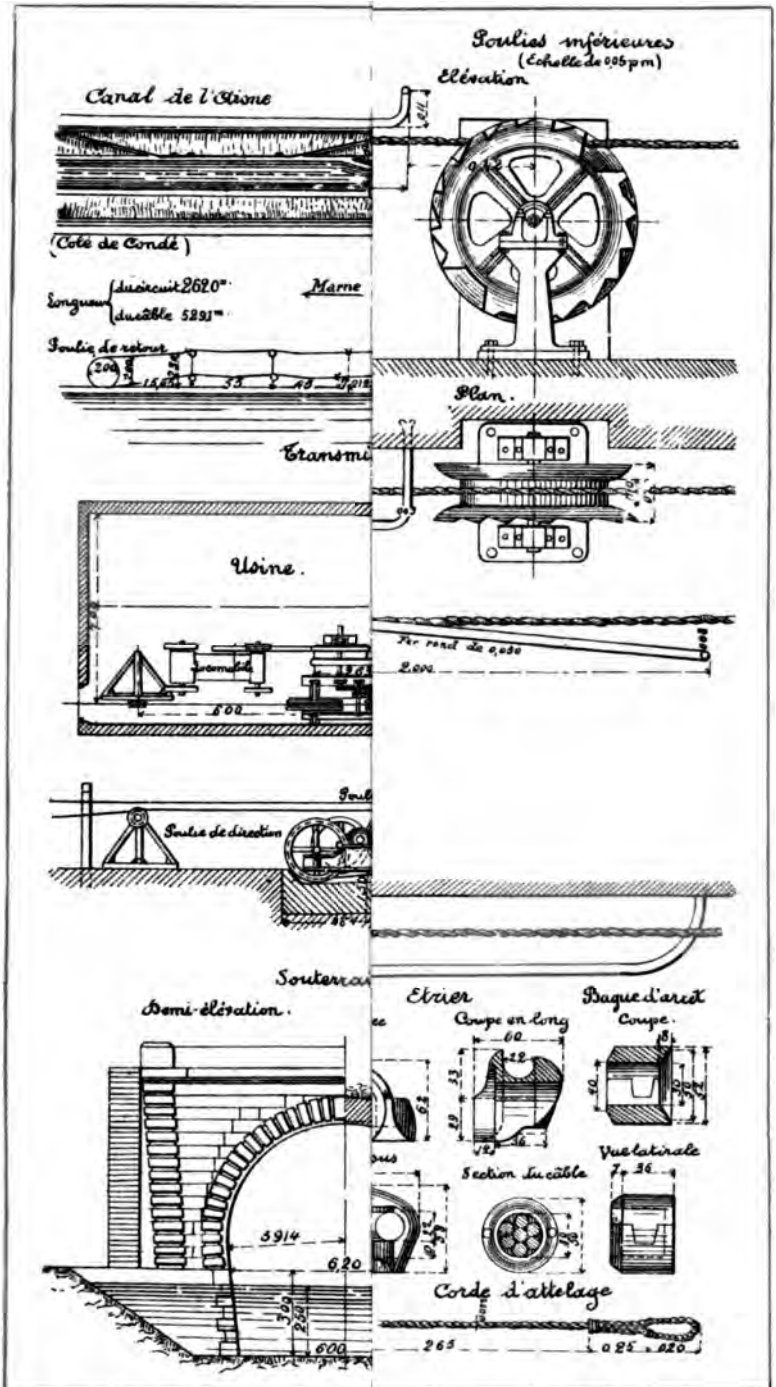
Poulies inférieures
(Échelle de 0,05 pm)
Élévation
Canal de l'Yssne
(Côté de Condé)
Marne
Plan.
Usine.
Poulie de direction
Souterrain
Demi-élévation.
Étrier
Bague d'arrêt
Coupe en long
Coupe.
Vue latérale
Section du câble
Corde d'attelage
5914
6,20
600
265

S Doc 30 56 1

A.

VIII

Plan.

bteur et du Treuil

Fig. 11.

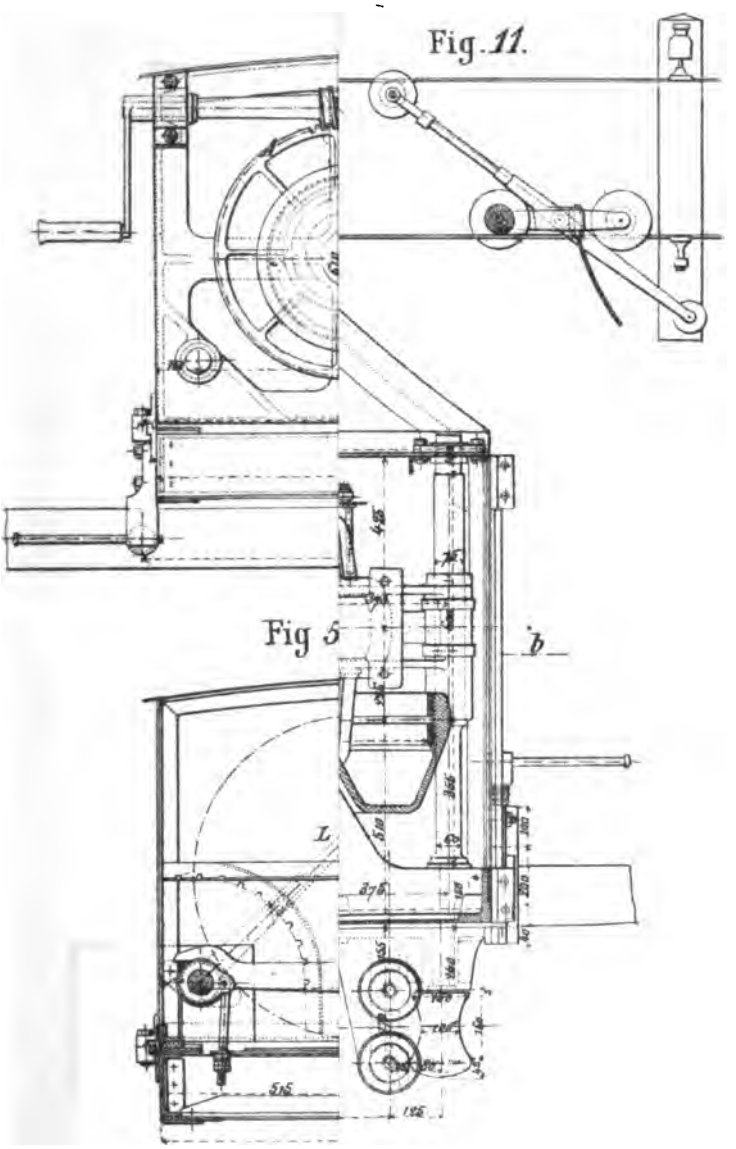

Fig 5

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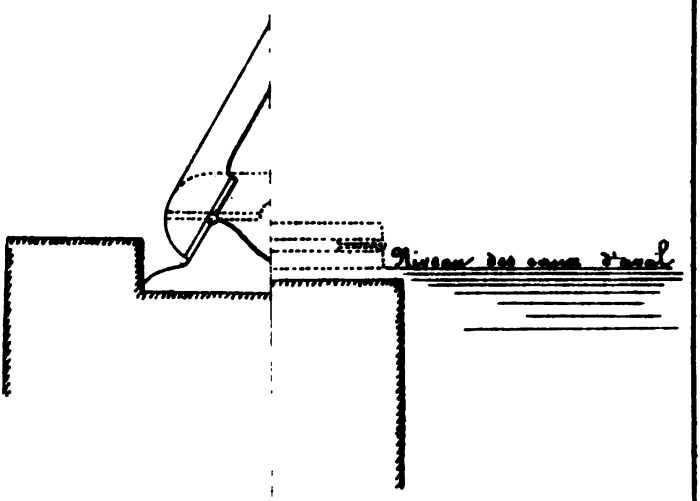
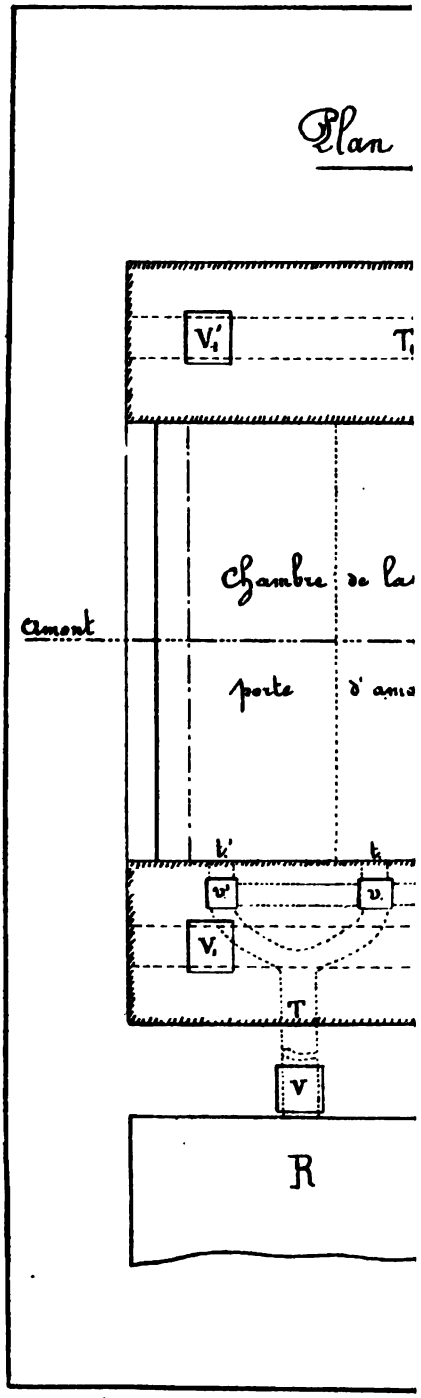
Coupe transversale
Porte

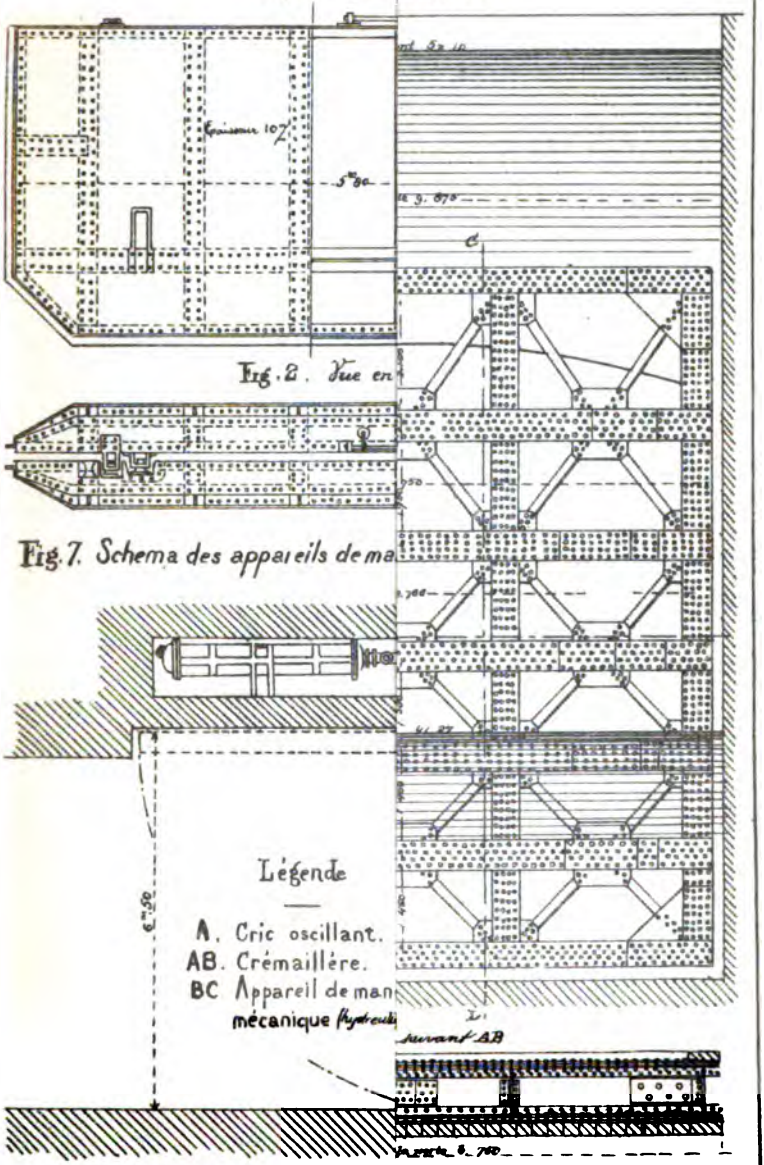
Echelle de 0.2




Plan
V'1
T1
Chambre de la
Amont
porte d'amo
k'
k
v'
v
V1
T
V
R

ASCENSEUR DES FONTS — *Porte d'aval du grand sas.*

Fig. 1. *Elévation.*



Echelle des fig. 1 à 36 : 0m,012 par mètre.

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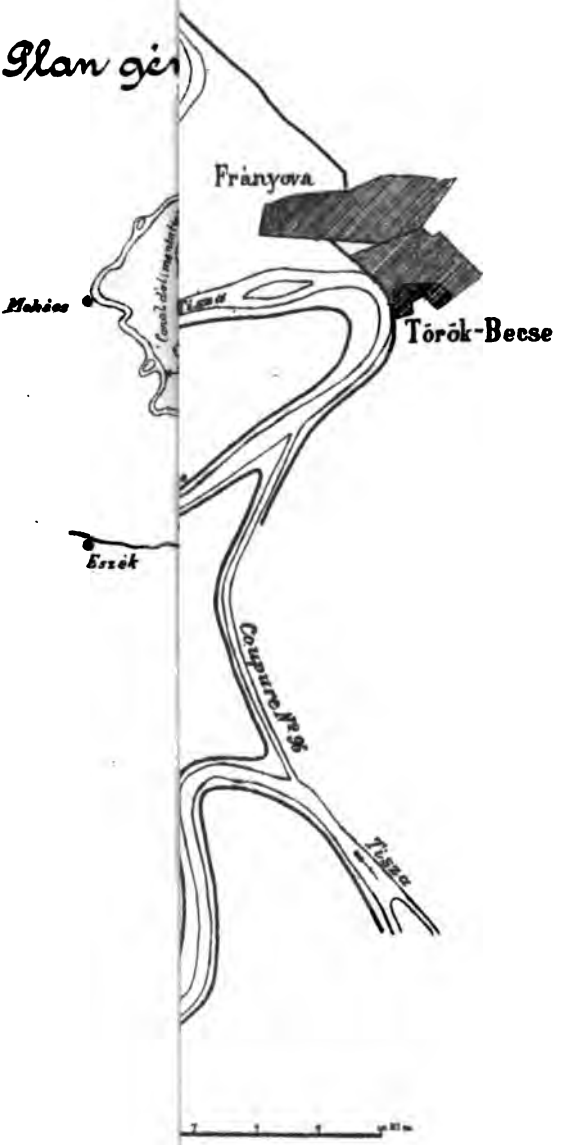
N°27

I.

anal François.

Plan gé



utowicz és-Társa Magyar földrajzi intézete Budapesten.

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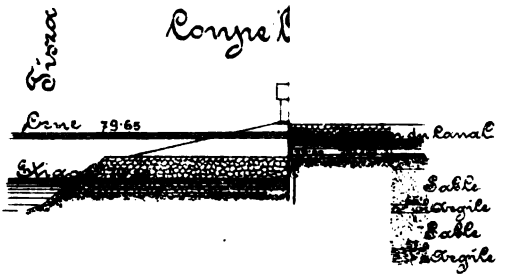
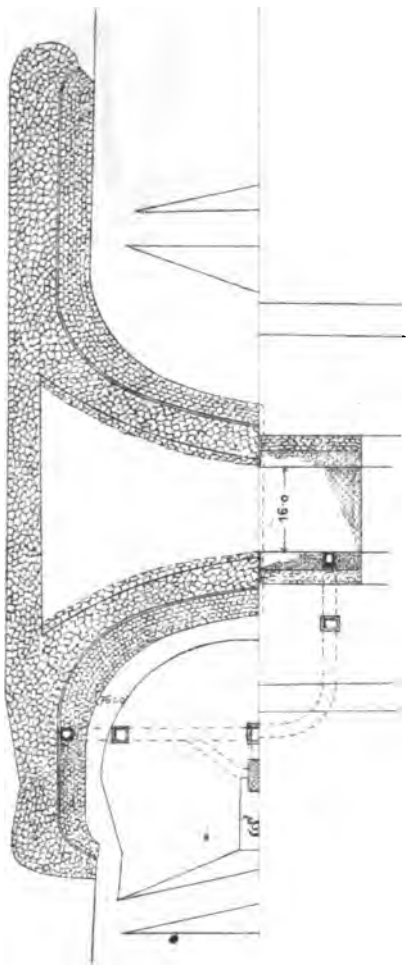
N°28

Nouvelle écluse près d'Ó-Becse 2.



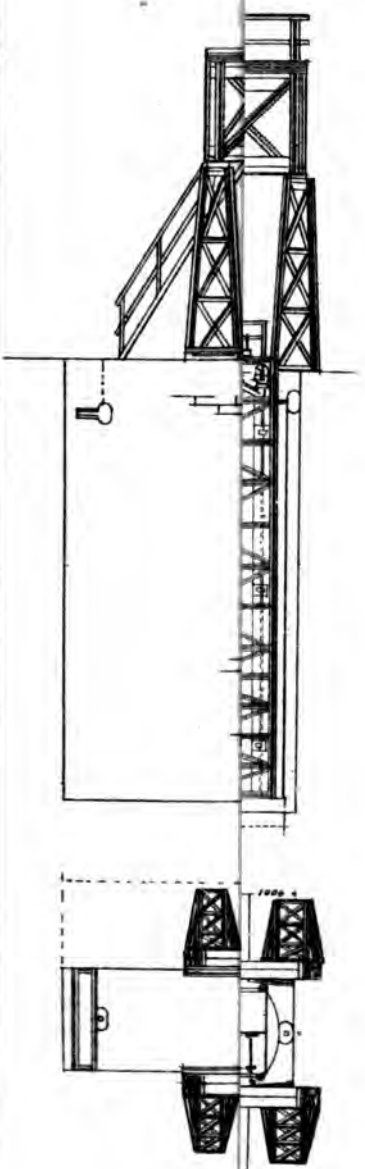


Lith. Kogutowicz és Társa Magyar földrajzi intézete Budapesten

S Doc 30 56 1

grie.)

erticales.



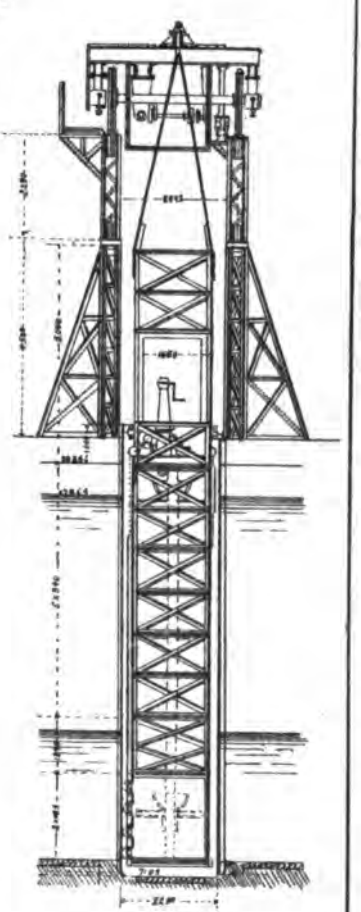
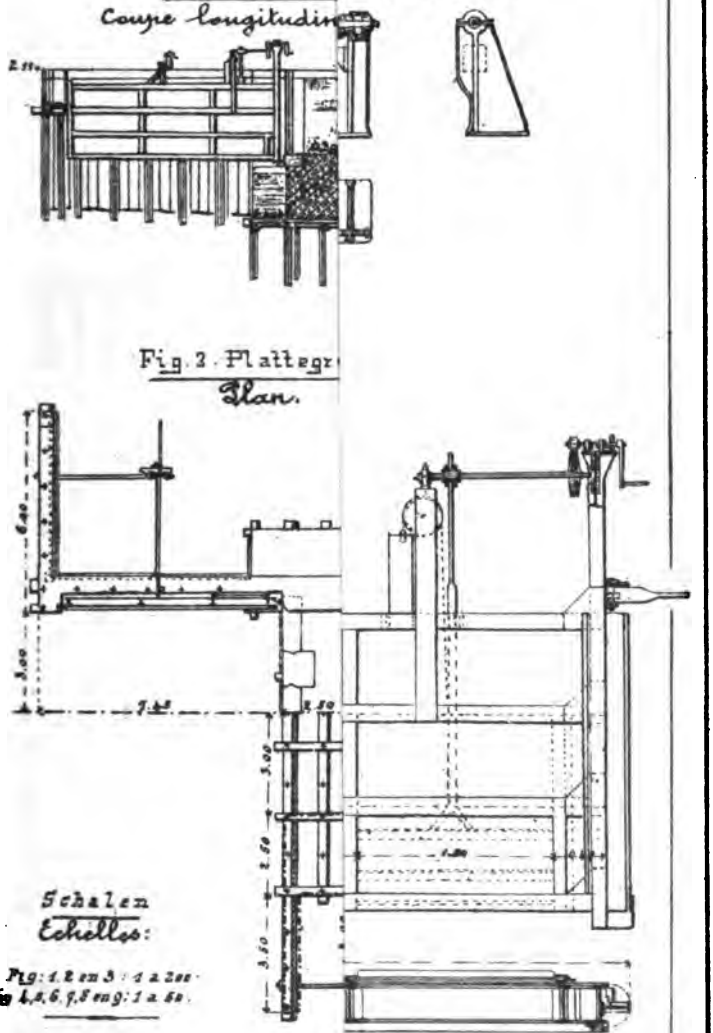


Fig.1 Doorsne
Coupe longitudi

Fig.2 Plattegr
Plan.

Fig.7 Dwpers.
Cabestan.



Schalen
Echelles:

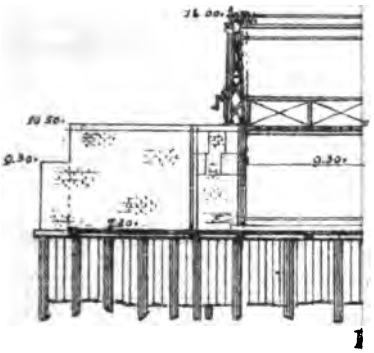
Fig: 1, 2 en 3 : 1 à 200
Fig 4, 5, 6, 7, 8 en 9 : 1 à 50.

S Doc 30 56 1

ONTLASTSLUIS MET HEFD
OF HET COEVORDERKANAA

Ecluse de décharge avec portes sur le Coevorderkanaa

Fig. 1.
Elévati



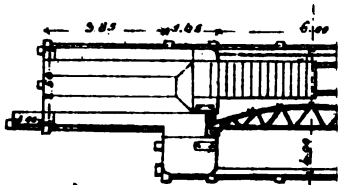
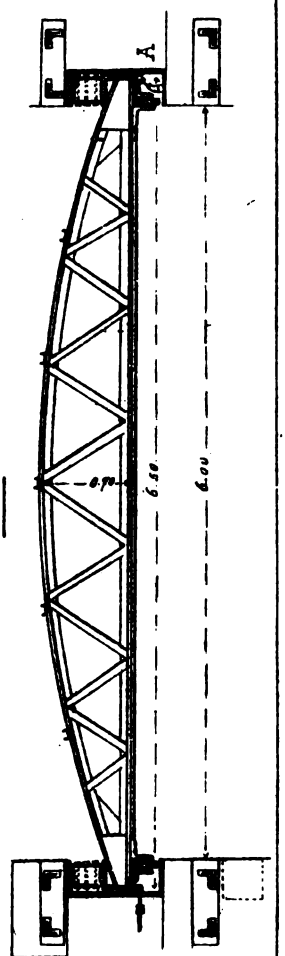


Fig. 4.



Détails der waterdichte afsluiting by A

Détails du joint étanche en A.

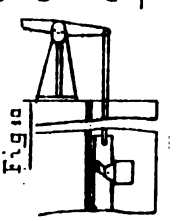


Fig 10

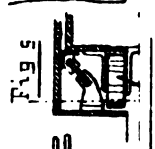


Fig 9

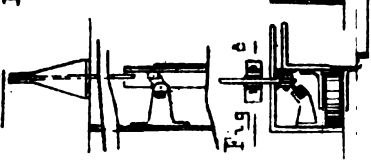


Fig 7

Fig 8

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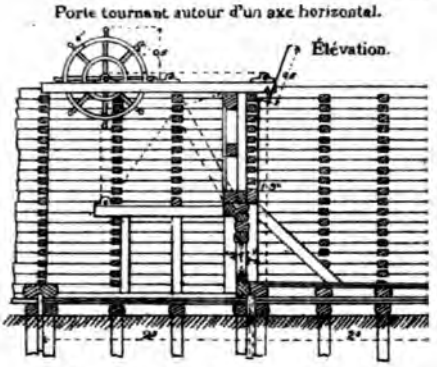
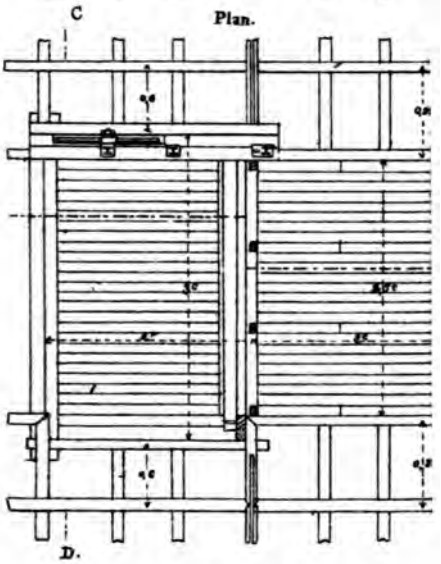
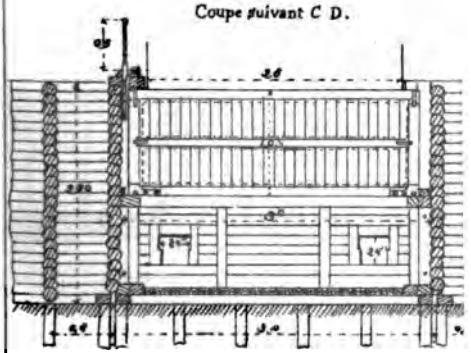
Portes d'écluse

Porte tournant autour d'un axe horizontal.





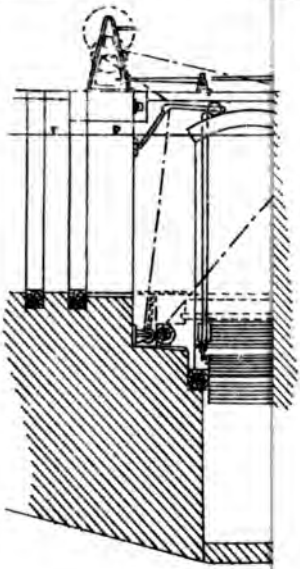
Coupe suivant C D.



N°37

SCHNAPP

Blatt I.



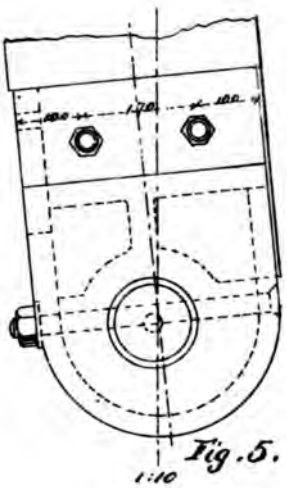


Fig. 5.

1:10

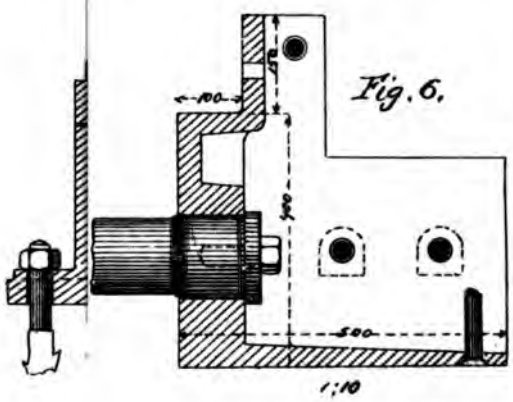


Fig. 6.

1:10

x Sprée.

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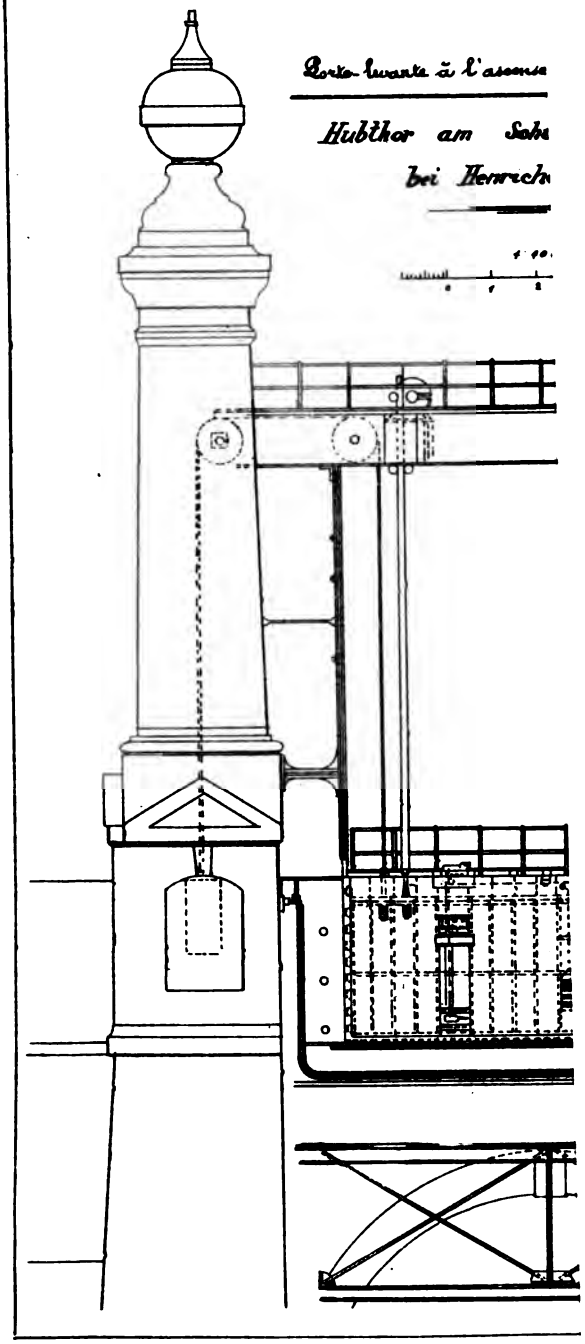
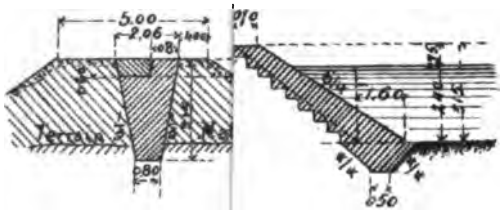
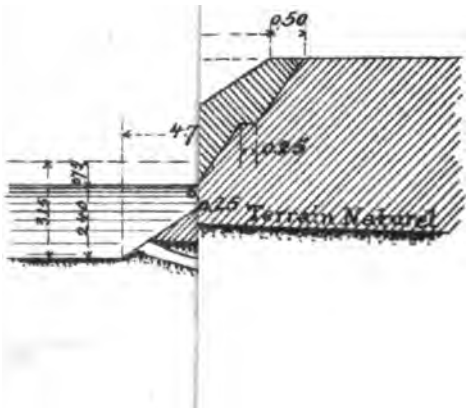
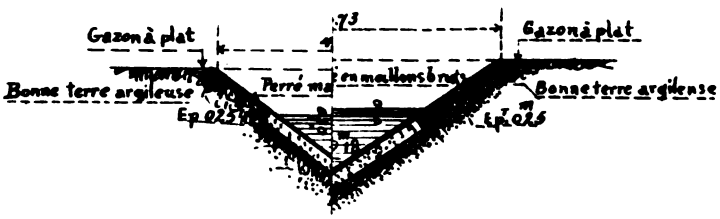

Porte tournante à l'ascens
Hubthor am Saba
bei Henrech

H. GENARD

fig. 3.







No 38

Fig 4

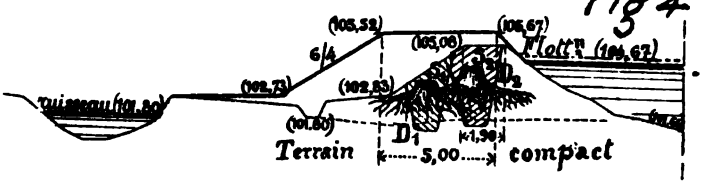


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figure 1.

Coupe transversale

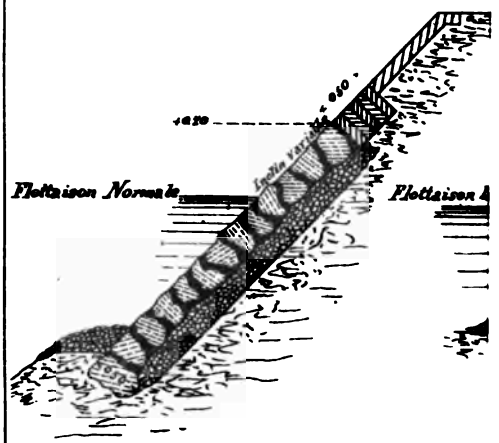
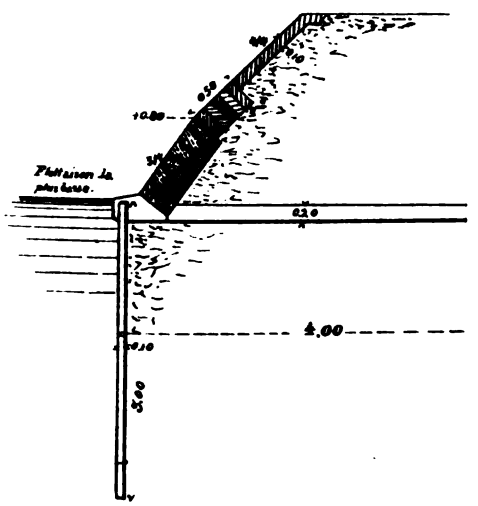


figure 2.

Coupe suivant A.B.



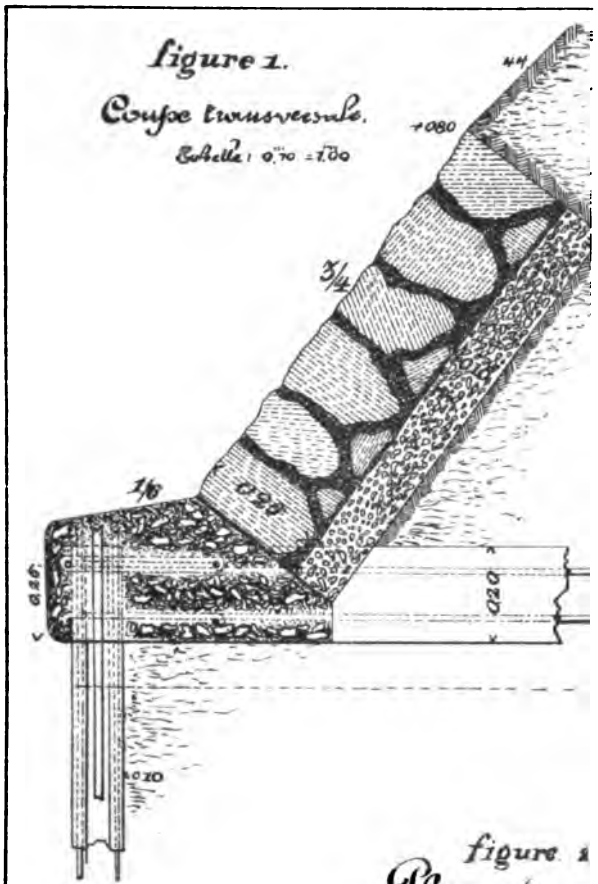
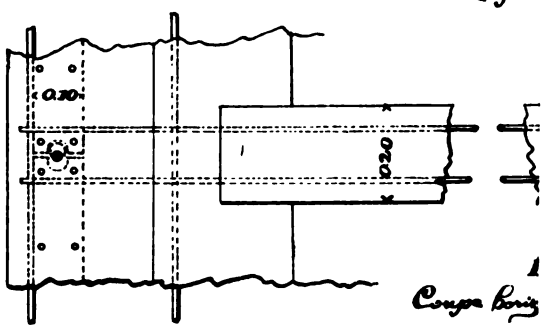
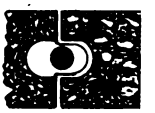


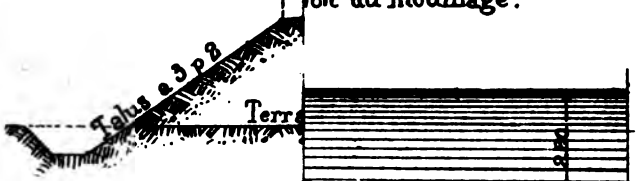
Figure
Plan (pa



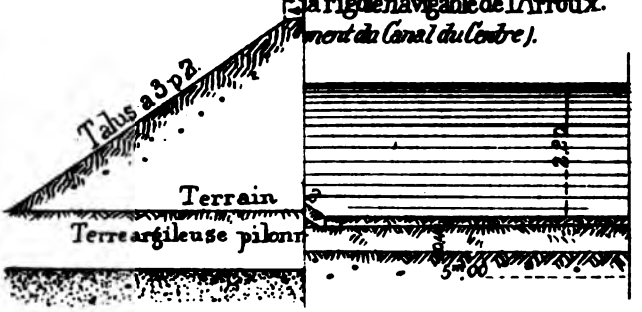
Coupe



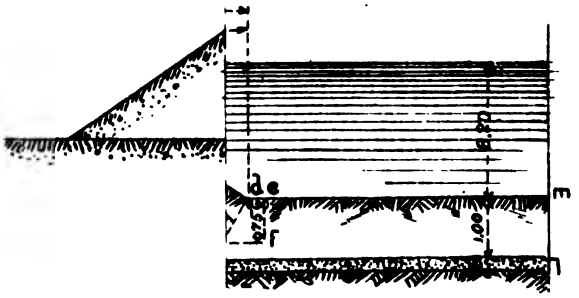
Profil N°1. Dér de la Marne au Rhin
Corr corroi avec indication ae
effectué comme conséquence
ion du mouillage.



Profil N°2. Déri
Corrois
la rigole navigable de l'Arroux.
ment du Canal du Centre).



Profil N°3. Ca de la Marne a la Saône
Digu ment du bief de Humes).



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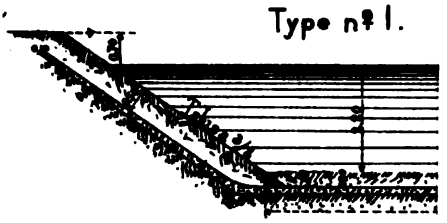
BET

Type nº I.



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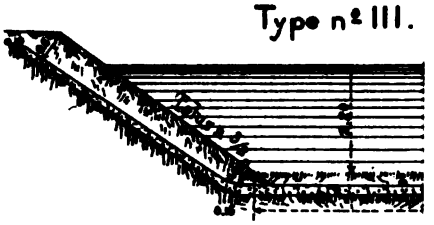

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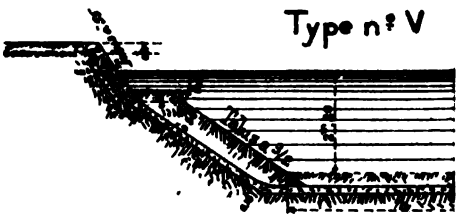

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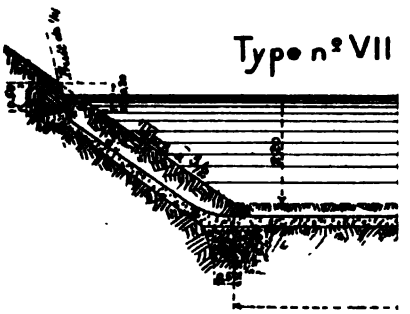


Ech

Roch
Canal

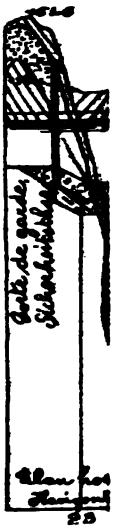
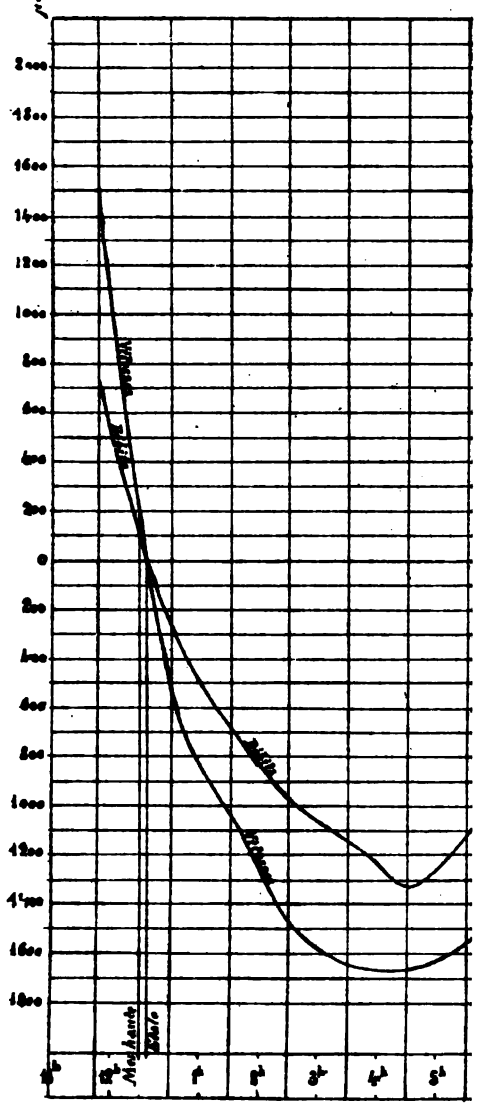


Diagramme des débits et

Échelles { Abcisses
Ordonnées



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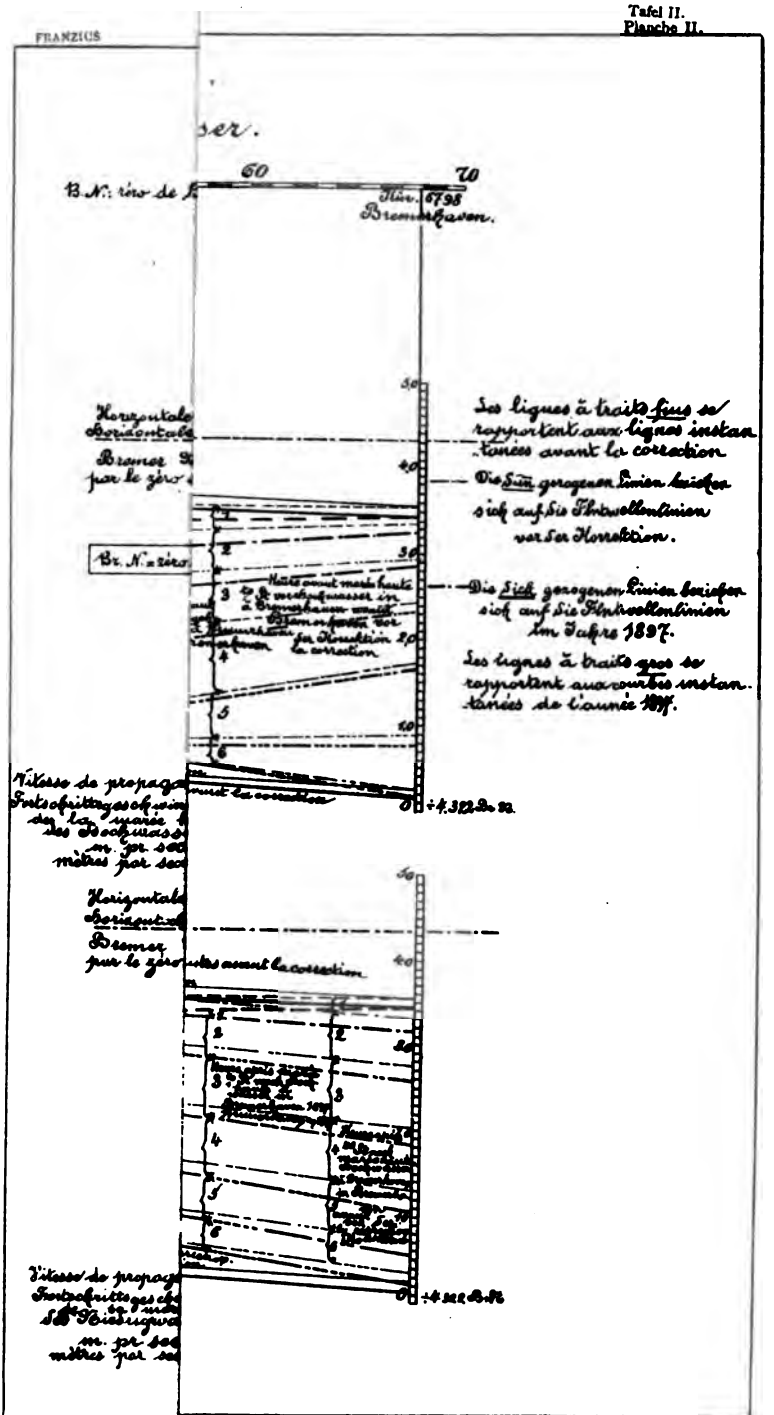
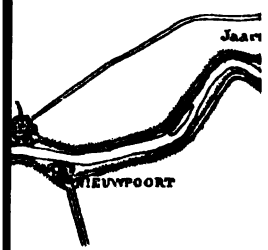
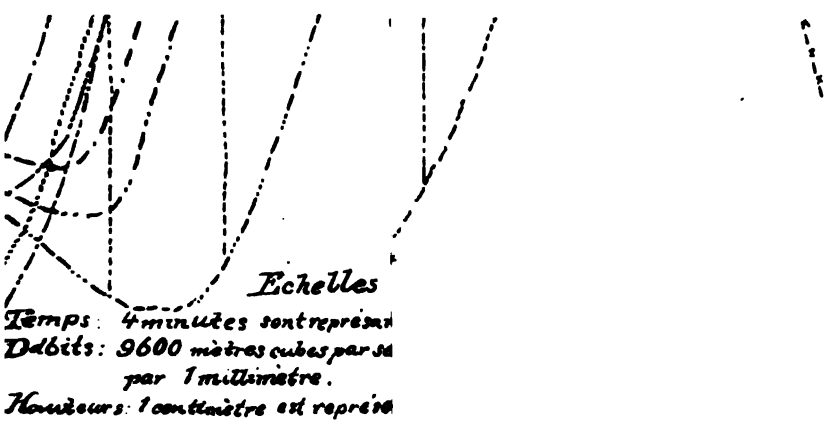
FRANZIUS


Ser.
60
70
Niv. 6798
Bremerhaven.
50
40
30
20
10
Br. N. = zéro
Die Linien gezogenen Linien beziehen sich auf die Pfahlreihenlinien vor der Korrektion.
Die Linien gezogenen Linien beziehen sich auf die Pfahlreihenlinien im Jahre 1897.
Les lignes à traits fins se rapportent aux lignes instantanées avant la correction
Les lignes à traits gras se rapportent aux lignes instantanées de l'année 1897.
Bremer
pour le zéro
0 +4.312 D. 98

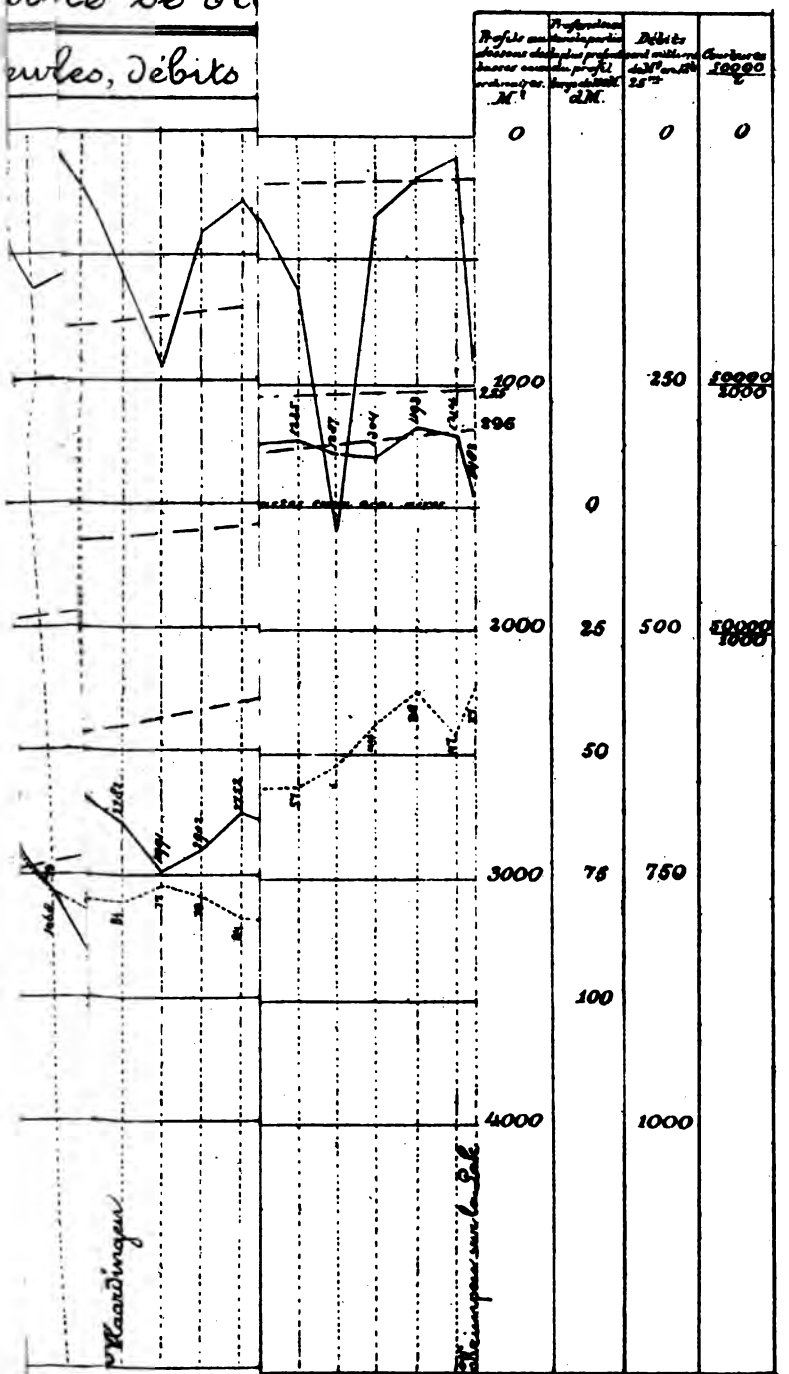
S Doc 30 56 1


Jaar
NIEUWPOORT

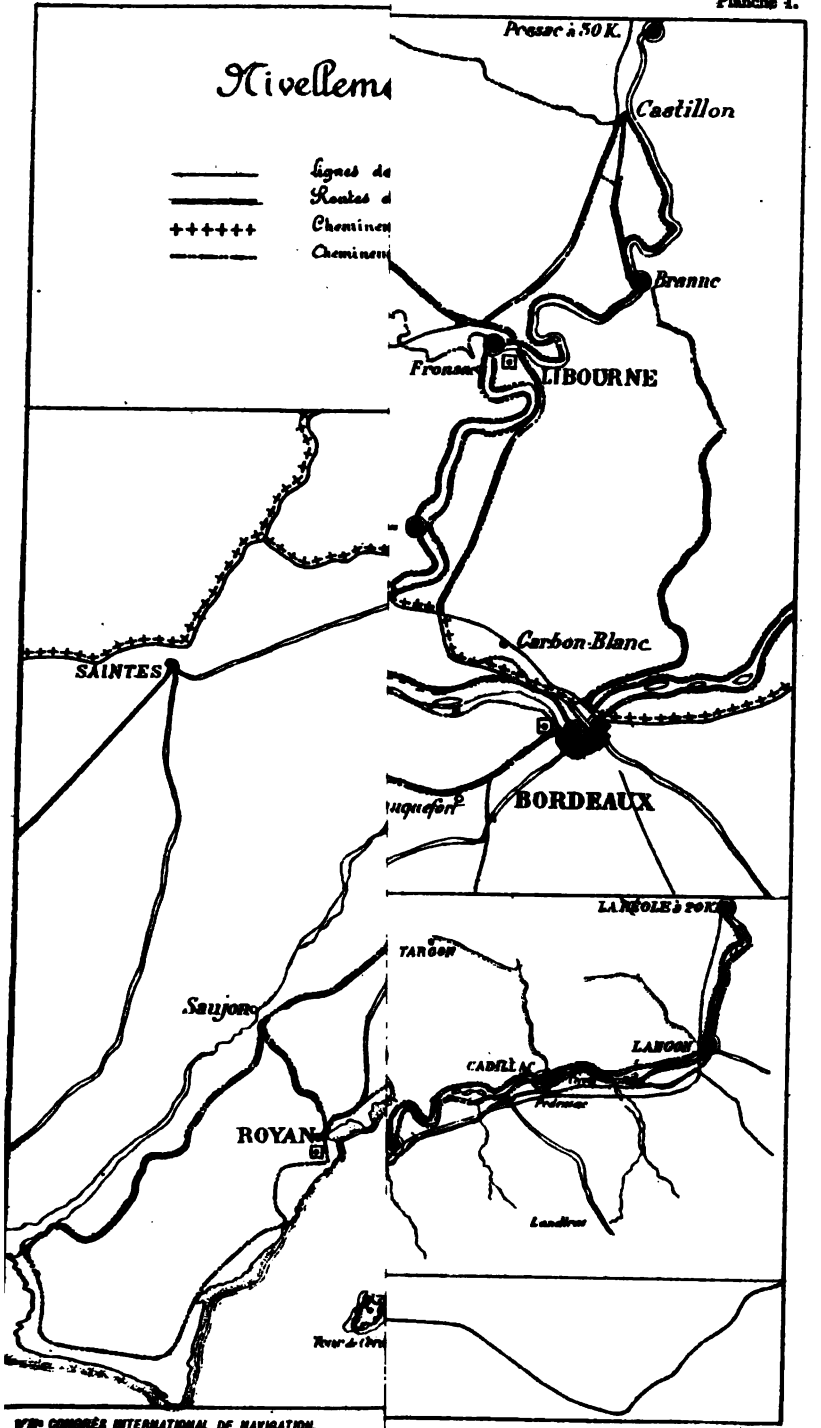

Echelles
Temps : 4 minutes sont représ
Débits : 9600 mètres cubes par
par 1 millimètre.
Hauteurs : 1 centimètre est repré

...uvle de R...

...eules, Débits



N°58
Planche I.



S Doc 30 56 1

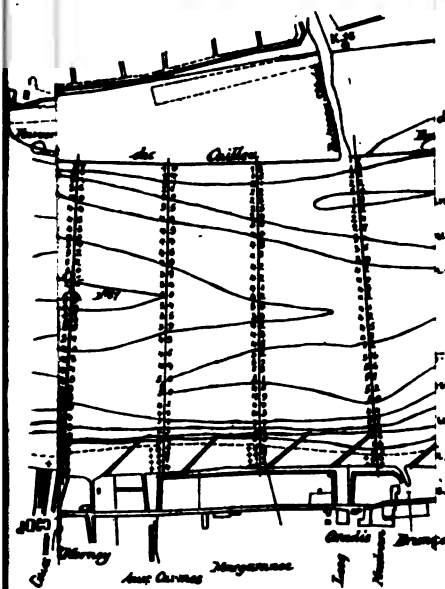
…s Mets.

Fig. 3. — Garonne_Ba… — Port de By…

1897 — 1/10000

Fig. 4 — Garonne_Bar…

1897 — 1/10000



…d'une partie des plans

…ne partie de la fig. (2…

…une partie des courbes de

…salité sur les plans annexés

…comportant toutes les traces

…rbes de niveau.

…sur des profils rigoureux

…les parcours de sonde sont

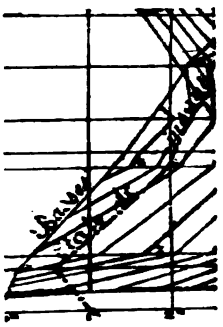
…és de 1 en 1 cm sur cette figure

…Brumpol dans les fig. 1 et 2 rappelé

Des eaux du bassin maritime

S Doc 56 1

S Doc 30 56 1



Les trois
royenne
ulieres gr
et 1895).

L'heure or
L'Echelle
L'Echelle

Les chiffres
bles en mel

M EBBE- UNI

IES DE MAI

sthacl

iacht d

No. 64

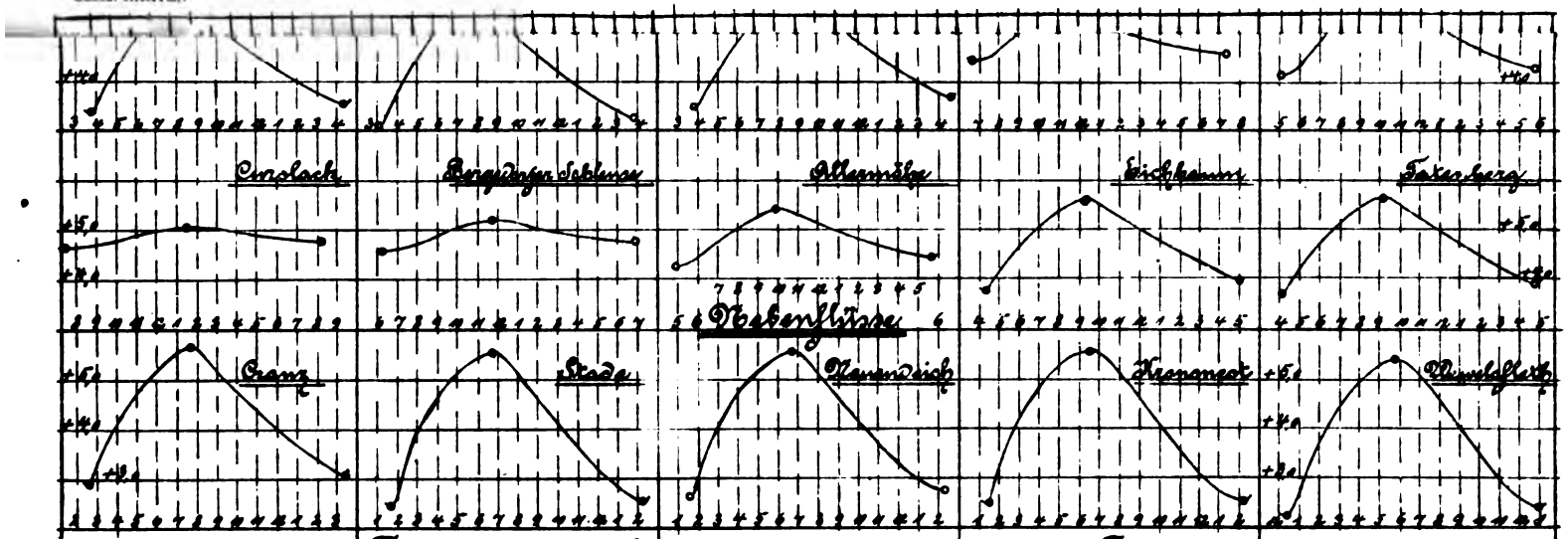
Blatt 2.

Planche 2.

ARTEN DER BESTIMMUNG DER WASSERMENGEN IM EBBE- UND FLUTHGEBIET

MODES DE CUBATURE DES VOLUMES DE MARÉE

Georg. HARTEN



Fluthkurven der Elbe vom Meere bis zur Fluthgrenze.

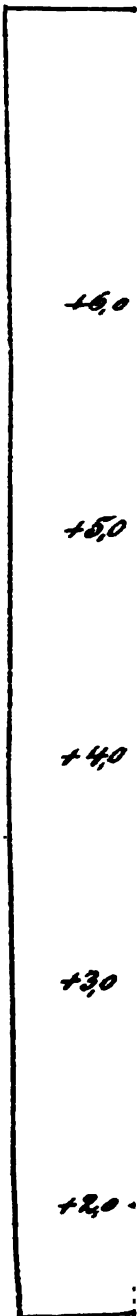
(Courbes de marée de l'Elbe, depuis la mer jusqu'à la limite de l'action de la marée.)

Die Ordinaten sind Höhen über Hamburger Null = −3,538 m Normal-Null.

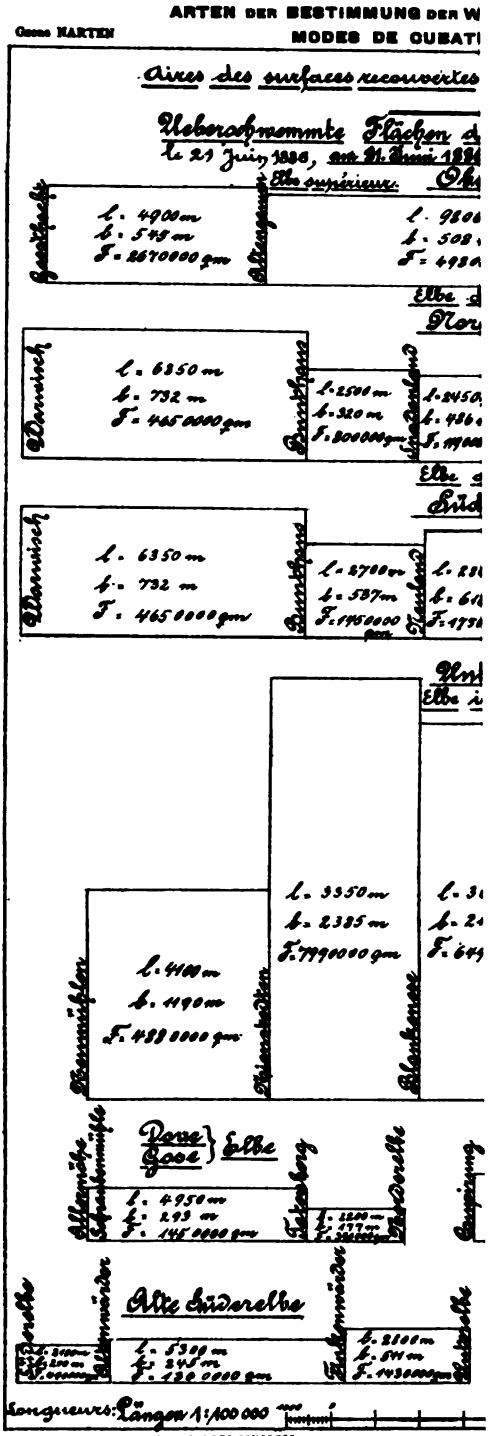
(Les ordonnées sont les hauteurs au-dessus du zéro de Hambourg = −3,538 m. zéro normal.)

(Hauteurs) Höhen 1:100. (Longueurs) Längen 1mm = 1 Stunde. (1 heure)

S Doc 30 ..... 56 1



VII. INTE
VII° CON


ARTEN DER BESTIMMUNG DER W
MODES DE CUBATI
Aires des surfaces recouvertes
Ueberschwemmte Flächen
le 21 Juin 1886, am 21. Juni 188
Elbe supérieure.
l. 4900 m
h. 545 m
F. 2670000 qm
l. 9806
h. 508
F. 4980
Elbe
Nor
Damnitsch
l. 6350 m
h. 732 m
F. 4650000 qm
Buschhaus
l. 2500 m
h. 320 m
F. 800000 qm
l. 2450
h. 486
Elbe
Süd
Damnitsch
l. 6350 m
h. 732 m
F. 4650000 qm
Buschhaus
l. 2700 m
h. 587 m
F. 1950000 qm
Nor
Elbe
l. 3350 m
h. 2385 m
F. 7990000 qm
l. 4110 m
h. 1190 m
F. 4890000 qm
Blankenese
Dove Gose
Elbe
l. 4950 m
h. 293 m
F. 1450000 qm
Altenwerder
Eichbaum
Finkenwärder
Altes Süderelbe
l. 5300 m
h. 245 m
F. 1300000 qm
l. 2100 m
h. 511 m
F. 1430000 qm
Longueurs: Längen 1:100 000

N°67

fig. 3.

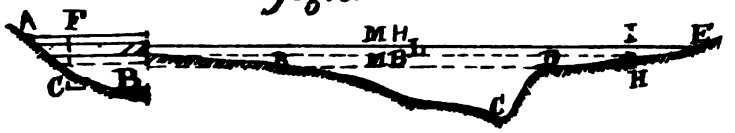


fig. 6.

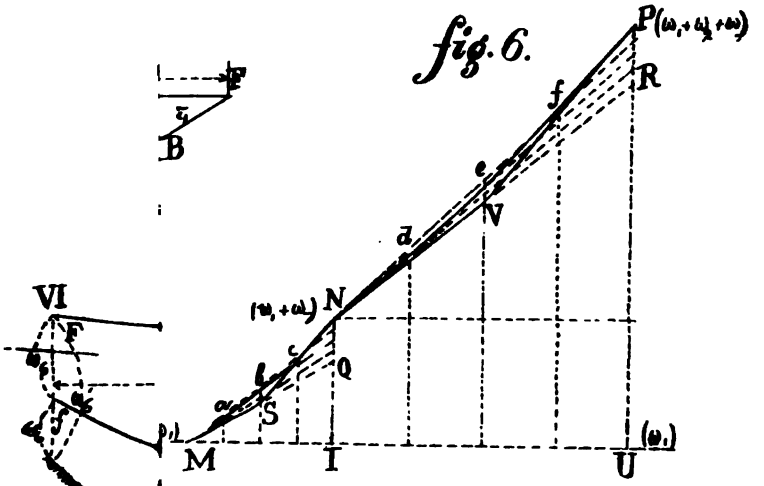
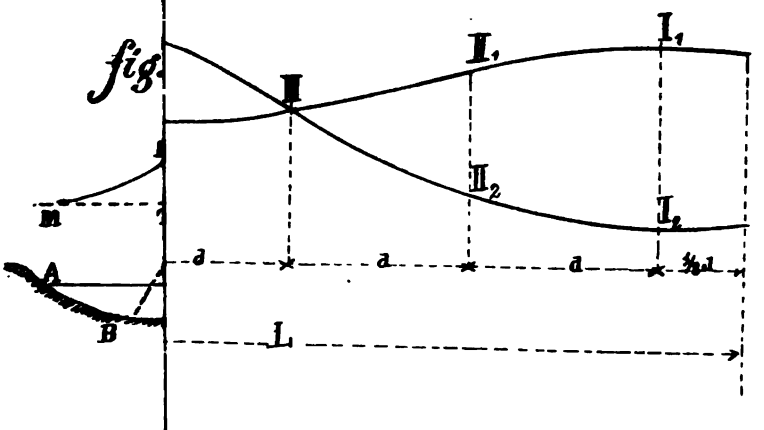


fig. 8.



MODES DE CUBATURE DES VOLUMES DE MARÉE

Fig. 1

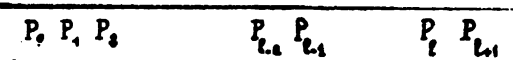


Fig. 5

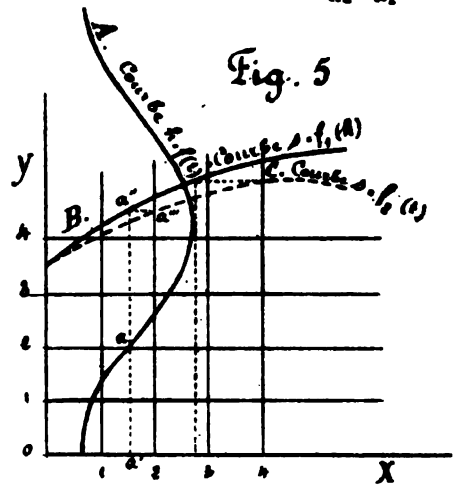
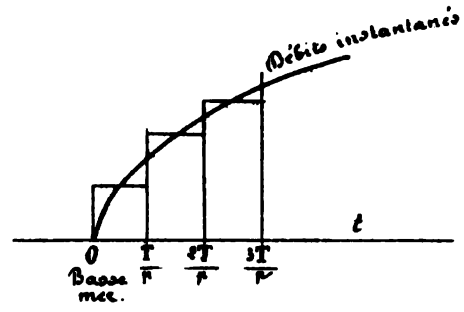


Fig. 2

Fig. 7

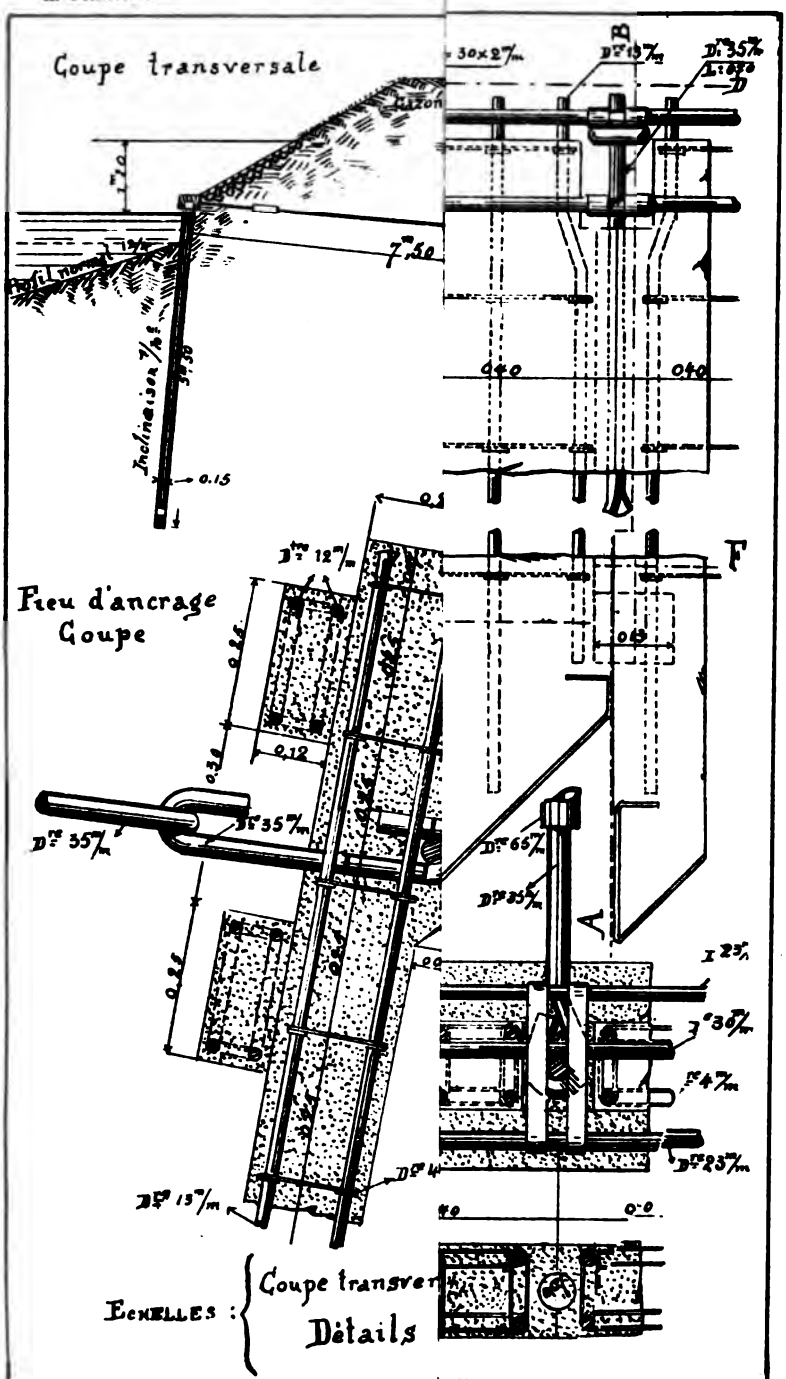


S Doc 30 56 1

L. GRENIER

N° 70

Planche II.



VIIe CONGRES INTERNATIONAL DE NAVIGATION.

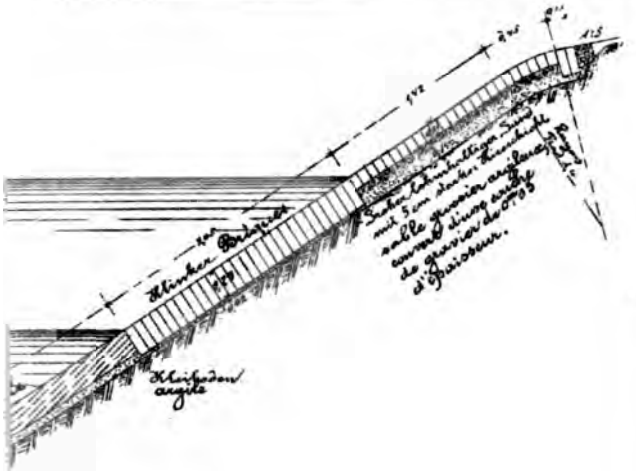
TROISIÈME SECTION. — 3e QUESTION

S Doc 30 56 1

N°71
Blatt I.

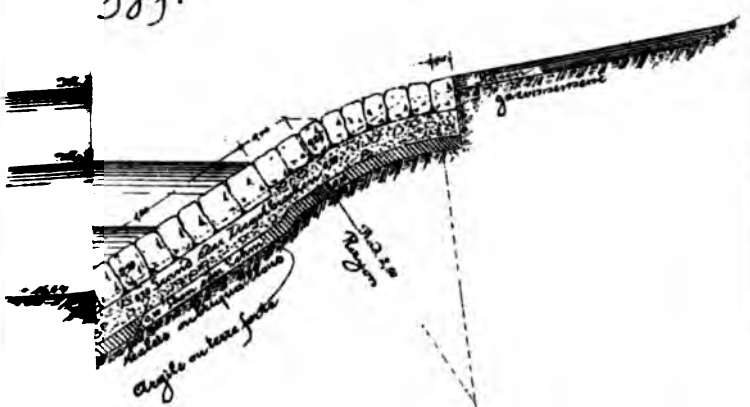
FÜL

Planche I.



1:50

fig. 7.



1.50

VII. INT
VII° CO

S Doc 30 56 1

EICH

dem in den Sommern 1896 und 1897,

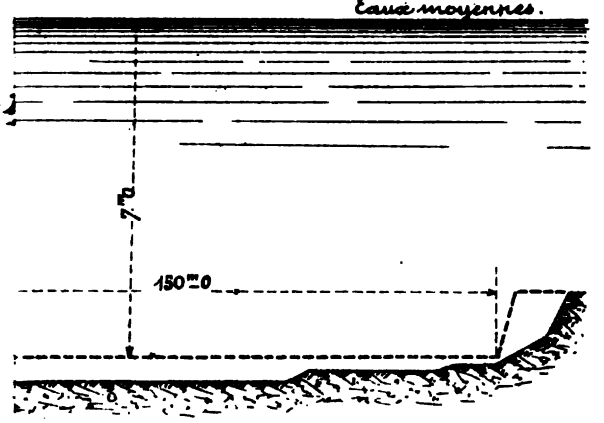
Est Fahrtskanal im Stettiner Haff (im großen Haff).

Cotes du chenal dragué dans la baie de Stettin

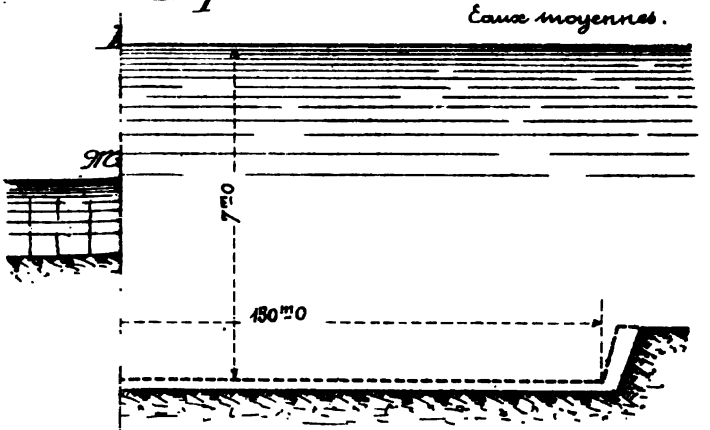
(Gr. Haff), pendant les étés de 1896 et de 1897.

Meiders Profil 1.

Oders.



Profil 2.



nktirt eingetragen.

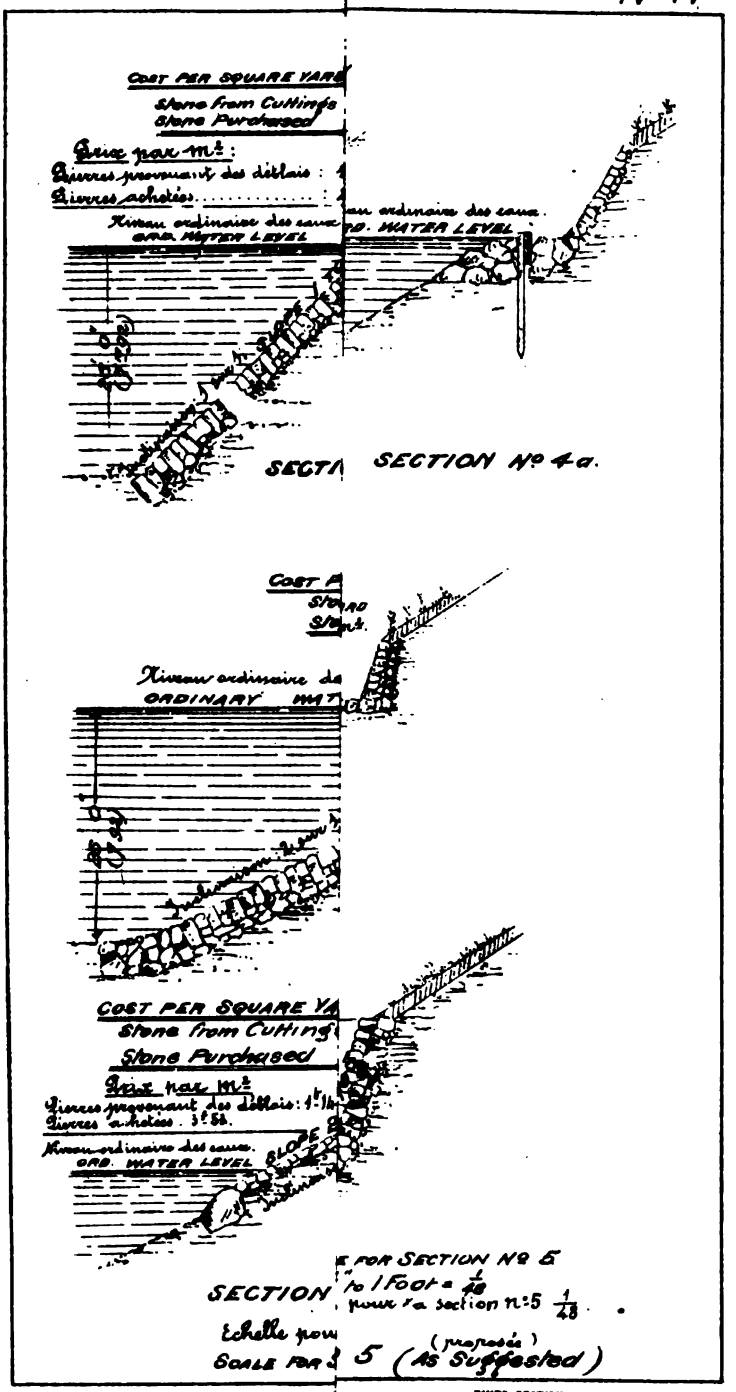
ndiqué par un trait pointillé.

1:1000. Höhen-Maßstab / Echelle des hauteurs } 1:100.

Name of vessel.	Dimensions.			1 slope.				1 in 6 rock slope.					
				Trough below normal.		Height crest to trough.		Speed (miles per hour).	Crest above normal.		Trough below normal.		Height crest to trough.
	Feet.	*Feet.*	*Feet.*	*Ft.*	*in.*	*Ft.*	*in.*		*Ft.*	*in.*	*Ft.*	*in.*	*Ft.* *in.*
Shandon	163.2	18.7	7.0	0	4	0	17	.....	.....		.....		.....
Do	128.5	16.0	7.3	0	8	1	9	.....	.....		.....		.....
Manx Fairy	128.5	16.0	7.3	.....		.....		.....	.....		.....		.....
Seal	210.7	28.4	14.4	1	3	1	10	8.72	0	9	0	8	0 12
Manchester	180.2	39.1	15.7	0	12	1	6	9.00	0	9	0	9	1 6
Yorkshire	142.2	25.2	11.5	0	4	0	9	13.28	1	1	0	5	1 6
Beta	145.5	30.4	10.7	0	1	0	4	9.23	1	0	0	9	1 9
Lestris	255.3	33.7	17.6	1	4	1	8	9.55	0	10	0	8	1 6
Dano	156.2	21.2	12.3	0	3	0	9	10.97	1	3	0	9	2 0
Bishop Rock	170.0	25.9	11.7	0	7	0	11	12.45	0	10	0	5	1 3
Charles Galloway	90.0	19.2	8.6	0	5	0	12	9.16	1	5	0	7	2 0
Do	.....	.....	.....	0	7	1	5	14.21	2	0	1	3	3 3

W. H. HUNTER

N°77



VIth INTERNATIONAL CONGRESS ON NAVIGATION
VIe CONGRÈS INTERNATIONAL DE NAVIGATION.

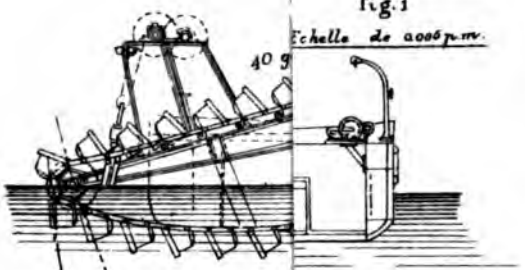
THIRD SECTION. — 3d QUESTION.
TROISIÈME SECTION. — 3e QUESTION.

L
VIIe

UE "SCHELDE III„

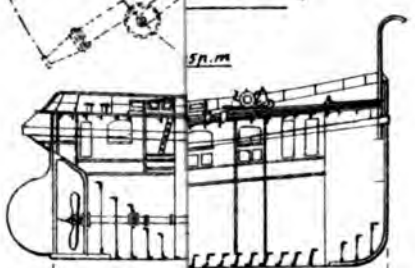
Fig. 1

Echelle de 0.005 p.m.



LDE II„

5p.m

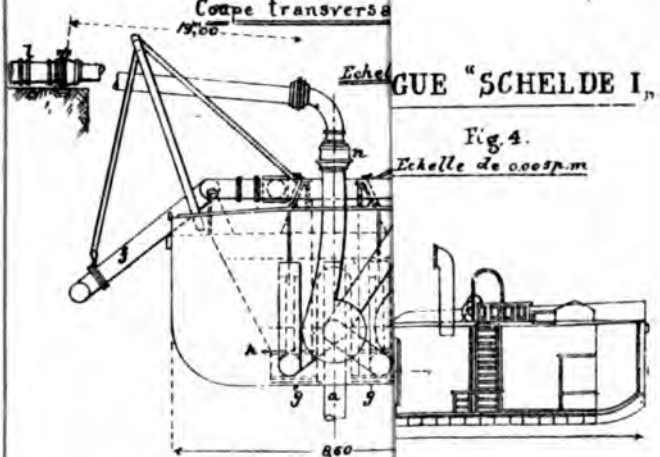


Coupe transversale

GUE "SCHELDE I„

Fig. 4.

Echelle de 0.005 p.m



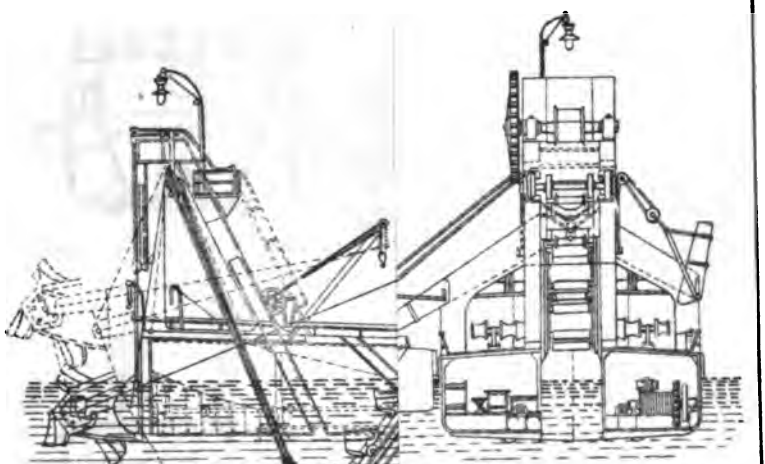
S Doc 30 56 1

N°80

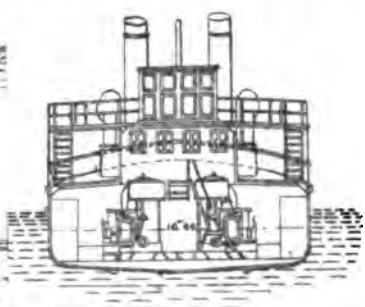
H. DESPREZ

Planche I.

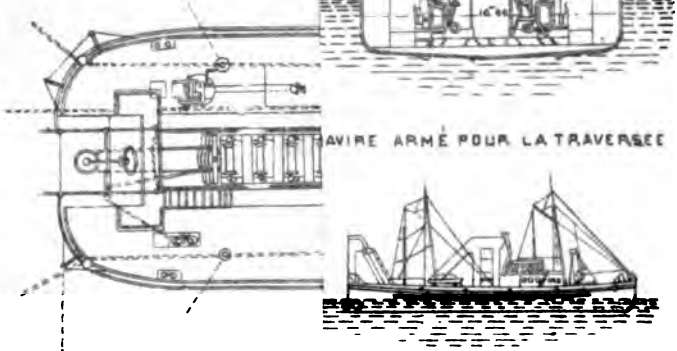
COUPE EN TRAVERS DU PUITS



COUPE A L'AVANT DE LA MACHINE

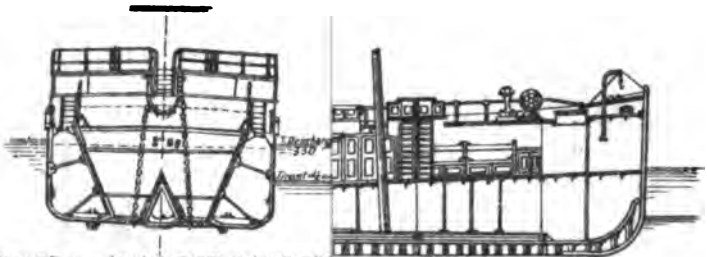


NAVIRE ARMÉ POUR LA TRAVERSÉE

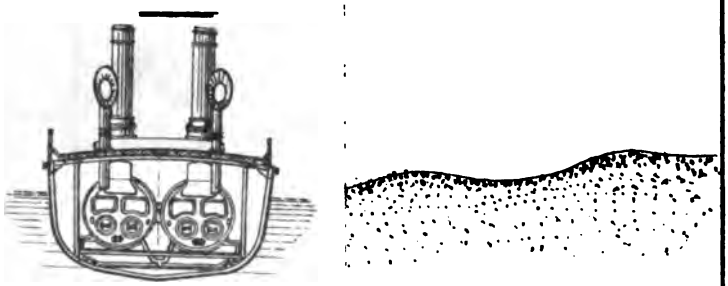


S Doc 30..... 56 1

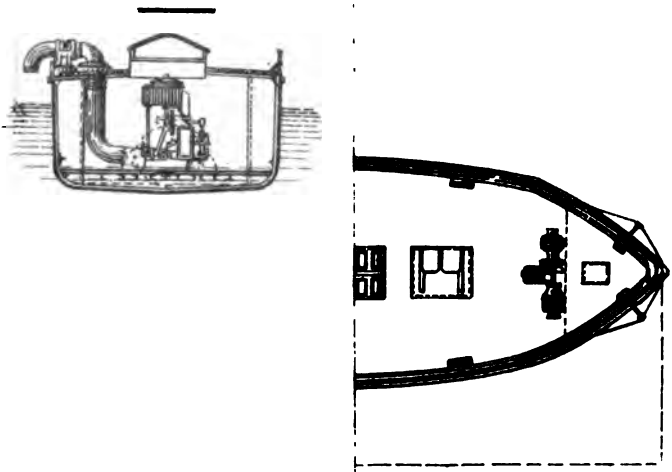
COUPE PAR LES PUITS A DEB



COUPE A L AVANT DES CHAUDIERE



COUPE A L'AVANT DE LA MACHINE



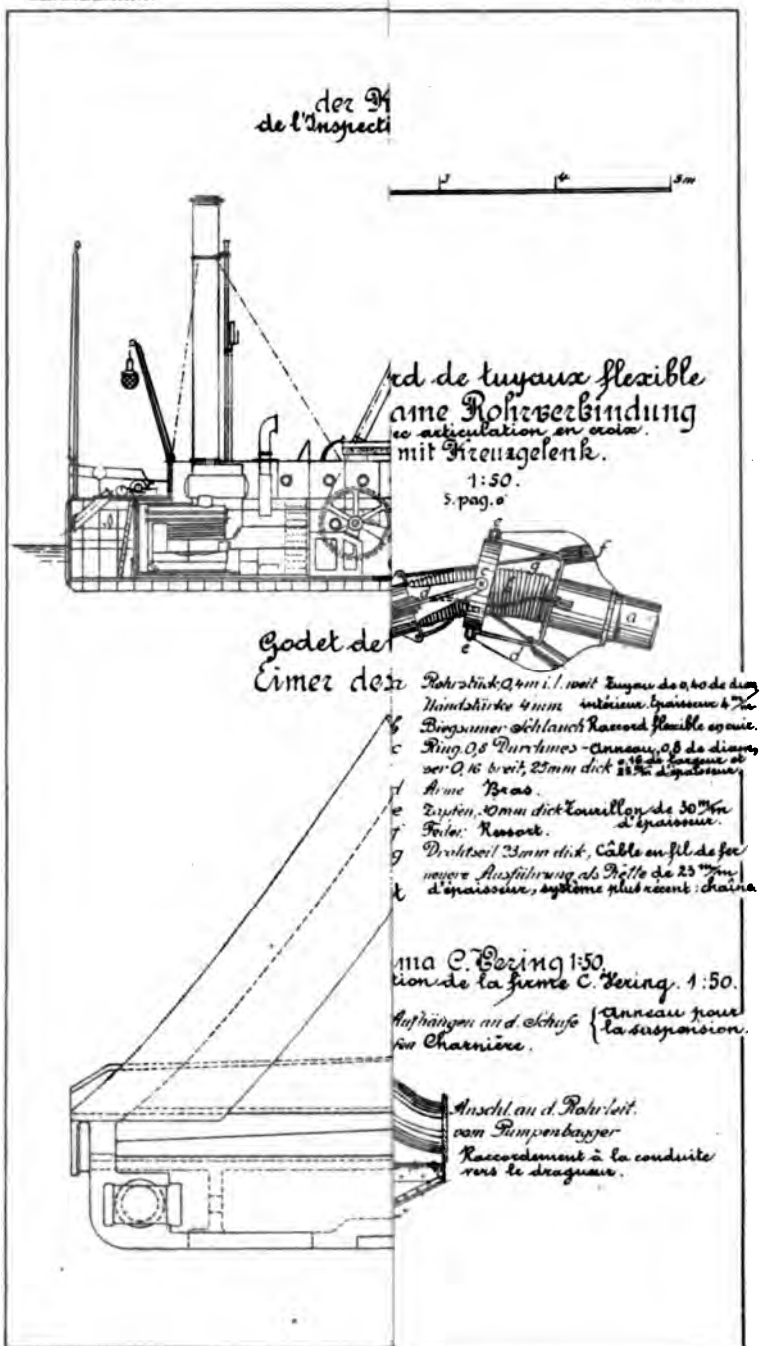
S Doc 30 56 1

N°82

Blatt I.

GERMELMANN

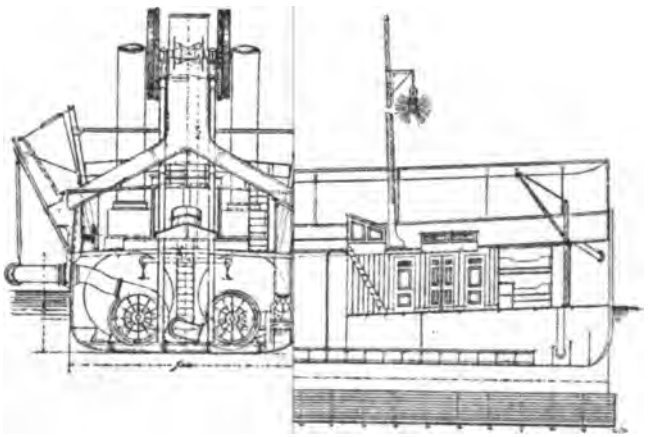
Planche I.

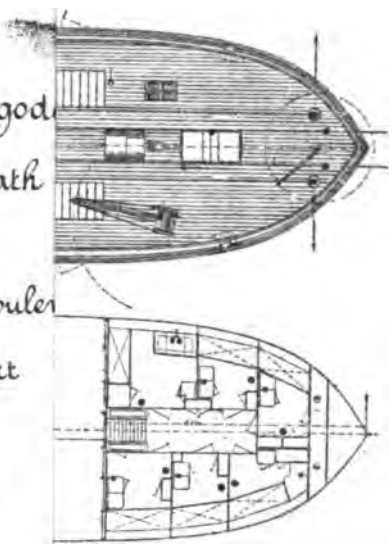

der
de l'Inspecti
rd de tuyaux flexible
ame Rohrverbindung
articulation en croix.
mit Kreuzgelenk.
1:50.
5. pag. e
Godet de
Eimer de
Rohrstück 0,4 m i. l. weit Tuyau de 0,40 de diam
Mantelstärke 4 mm intérieure épaisseur 4 m
Bingsumer Schlauch Raccord flexible en caoutc
Ring 0,8 Durchmes - Anneau 0,8 de diamè
ser 0,16 breit, 25 mm dick de largeur et
Arme Bras.
Zapfen, 40 mm dick Tourillon de 30 mm
Feder Ressort.
Drahtseil 23 mm dick, Câble en fil de fer
neuere Ausführung als Nette de 23 mm
d'épaisseur, système plus récent : chaîne
ma C. Hering 1:50.
ion de la firme C. Hering. 1:50.
Aufhängen an d. Schuss
Charnière.
anneau pour
la suspension.
Anschl. an d. Rohrleit.
vom Pumpenbagger
Raccordement à la conduite
vers le dragueur.

S Doc 30 56 1

N°85

J. Massalski. Planche II.





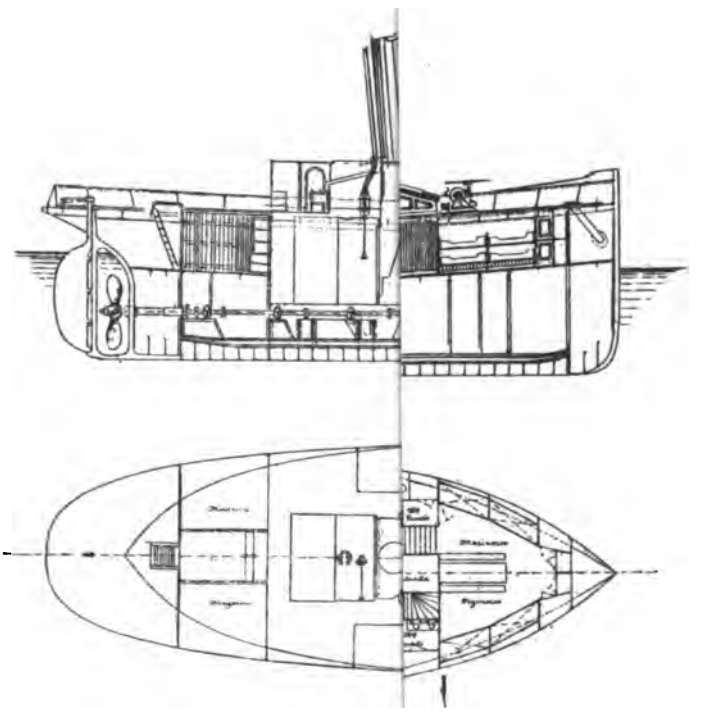
Deux dragues a godet
Simson et Goliath
avec
appareil de refouler
pour le port
de
Pillau

S Doc 30 56 1

N°86

J. Massalski.

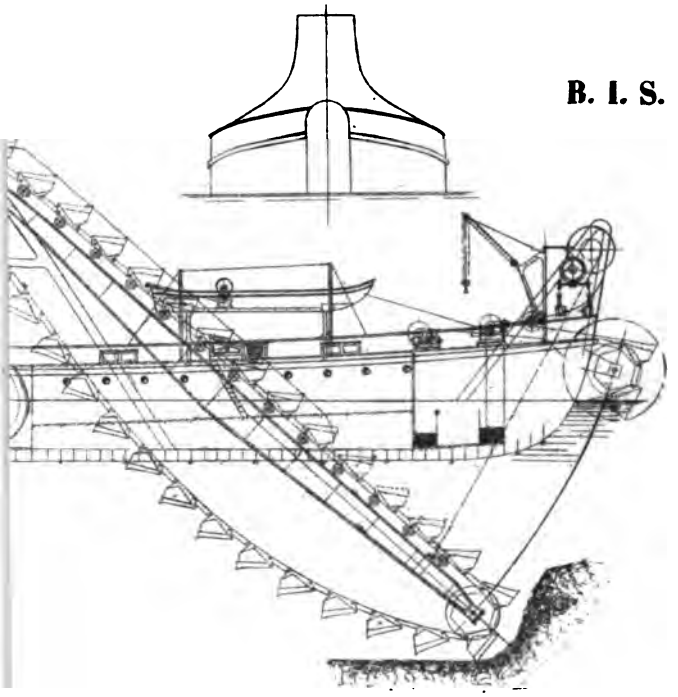
Planche III.

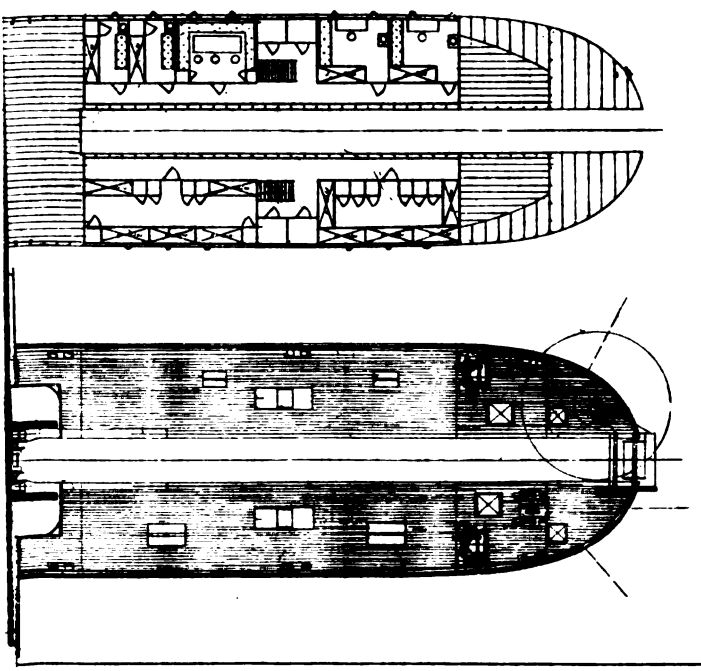


S Doc 30 56 1

N°89

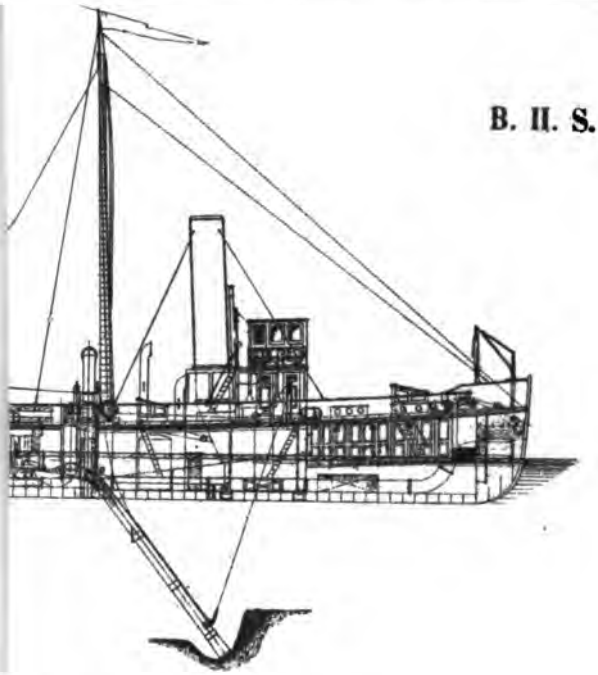
B. I. S.

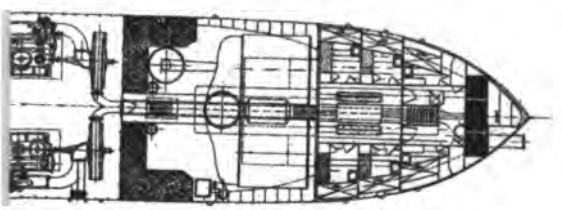


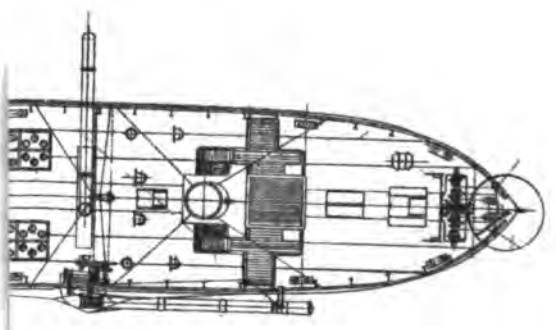


N°90

B. H. S.







. Gedrukt bij H. den Hartog te 's Gravenhage.

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N°91

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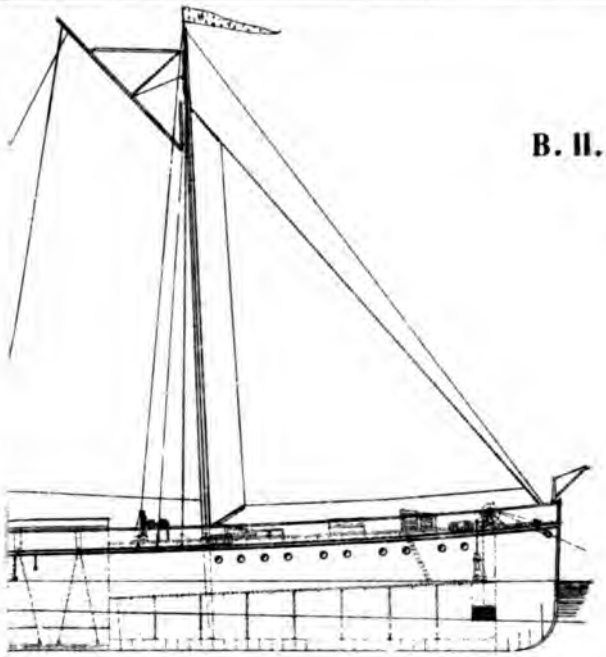

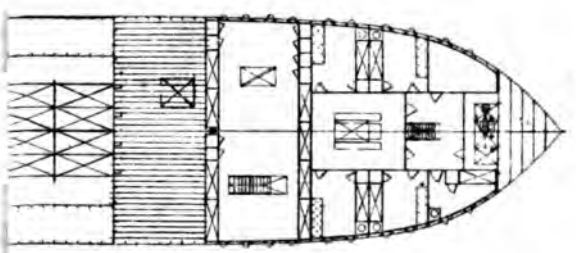

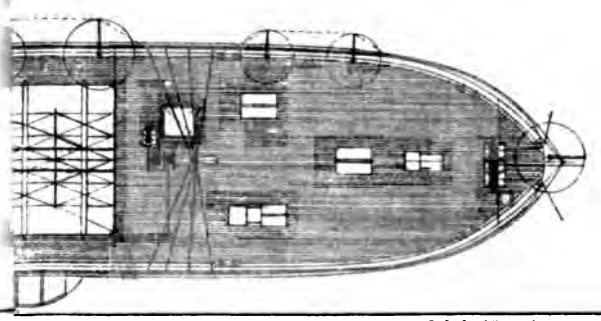

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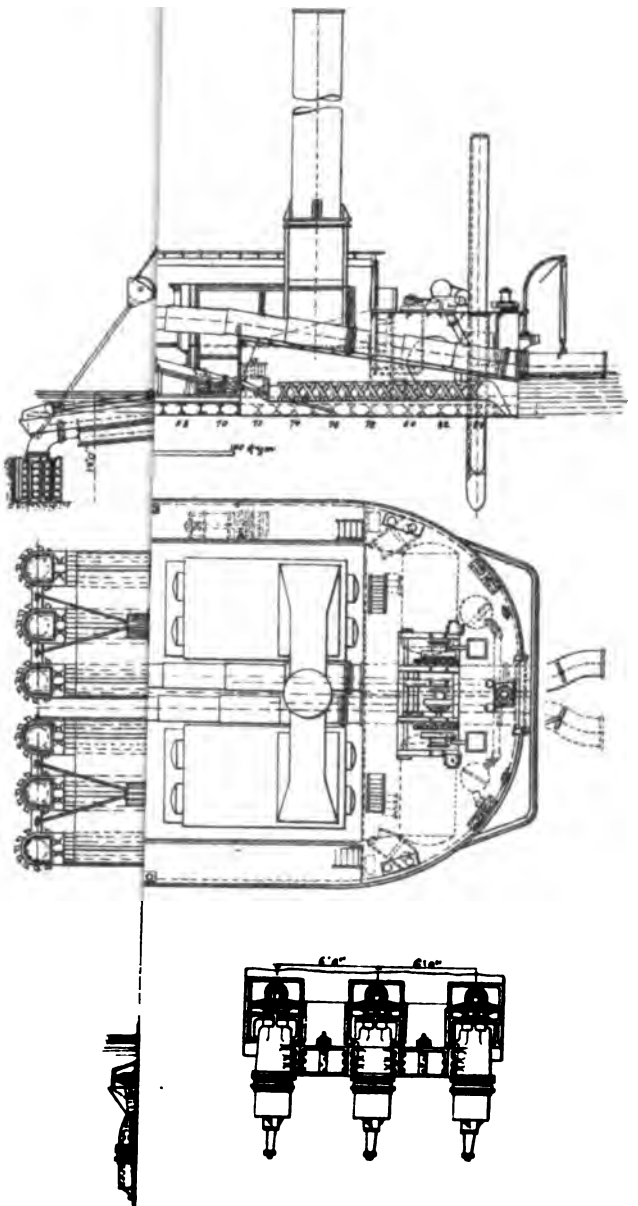

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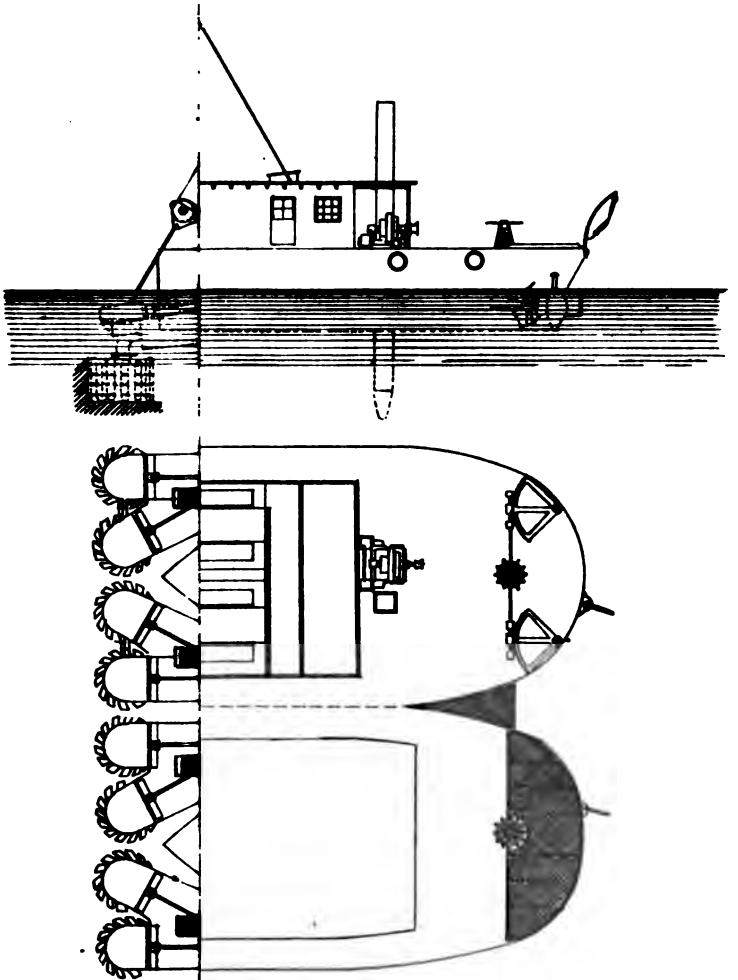
N°94

LINDON W. BATES

Pl. III.



VIIIth INTERNATIONAL CONGRESS O

VIIIe CONGRÈS INTERNATIONAL DE

THIRD SECTION. — 4th QUESTION.

TROISIÈME SECTION. — 4e QUESTION.

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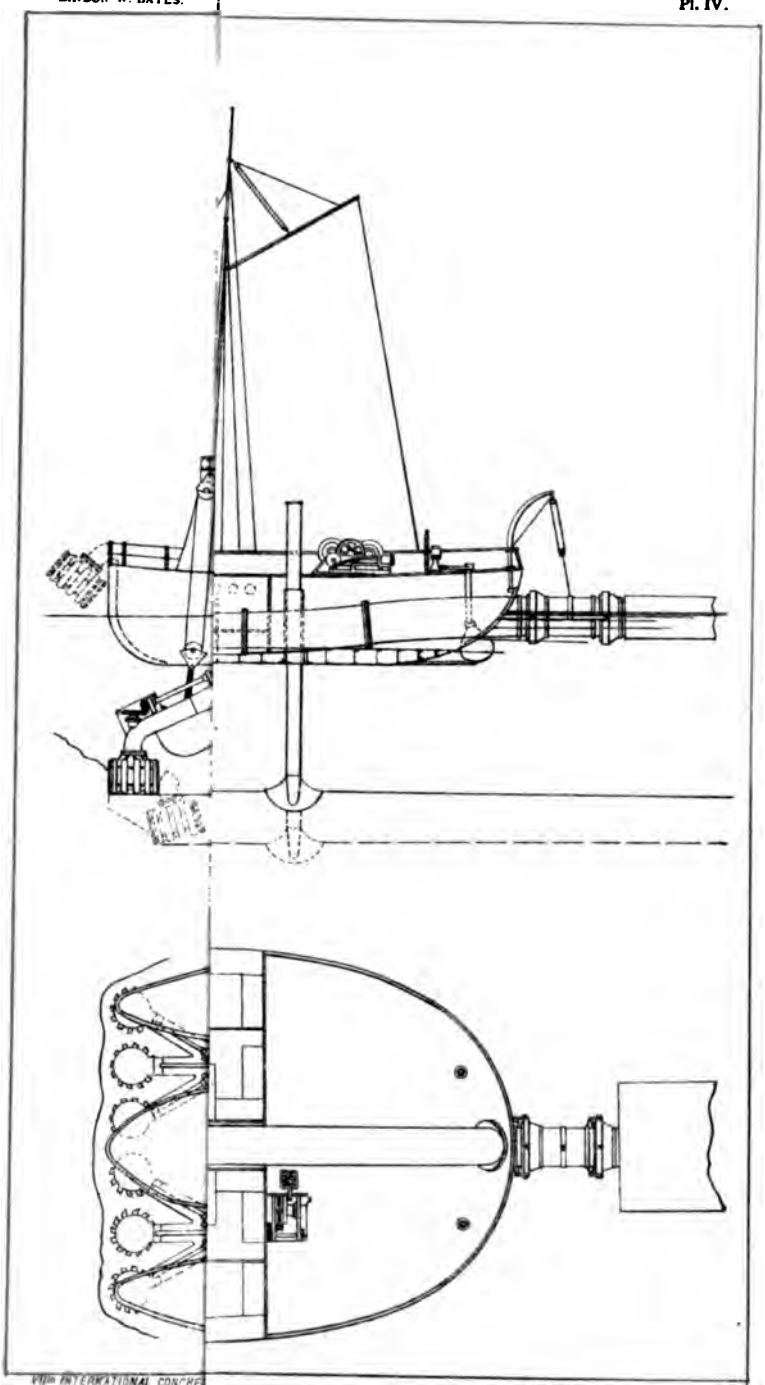
LINDON W. BATES.

N°95

Pl. IV.



VIIIe INTERNATIONAL CONGRES

VIIIe CONGRÈS INTERNATIONAL

THIRD SECTION. — 4th QUESTION.

TROISIÈME SECTION. — 4e QUESTION.

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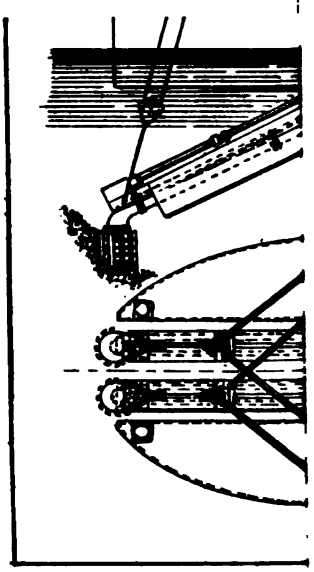

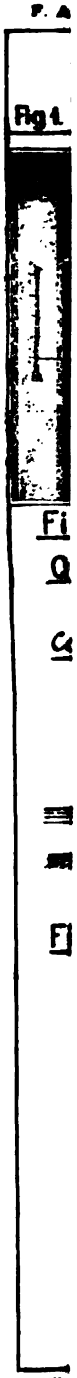
F. A
Fig 1.
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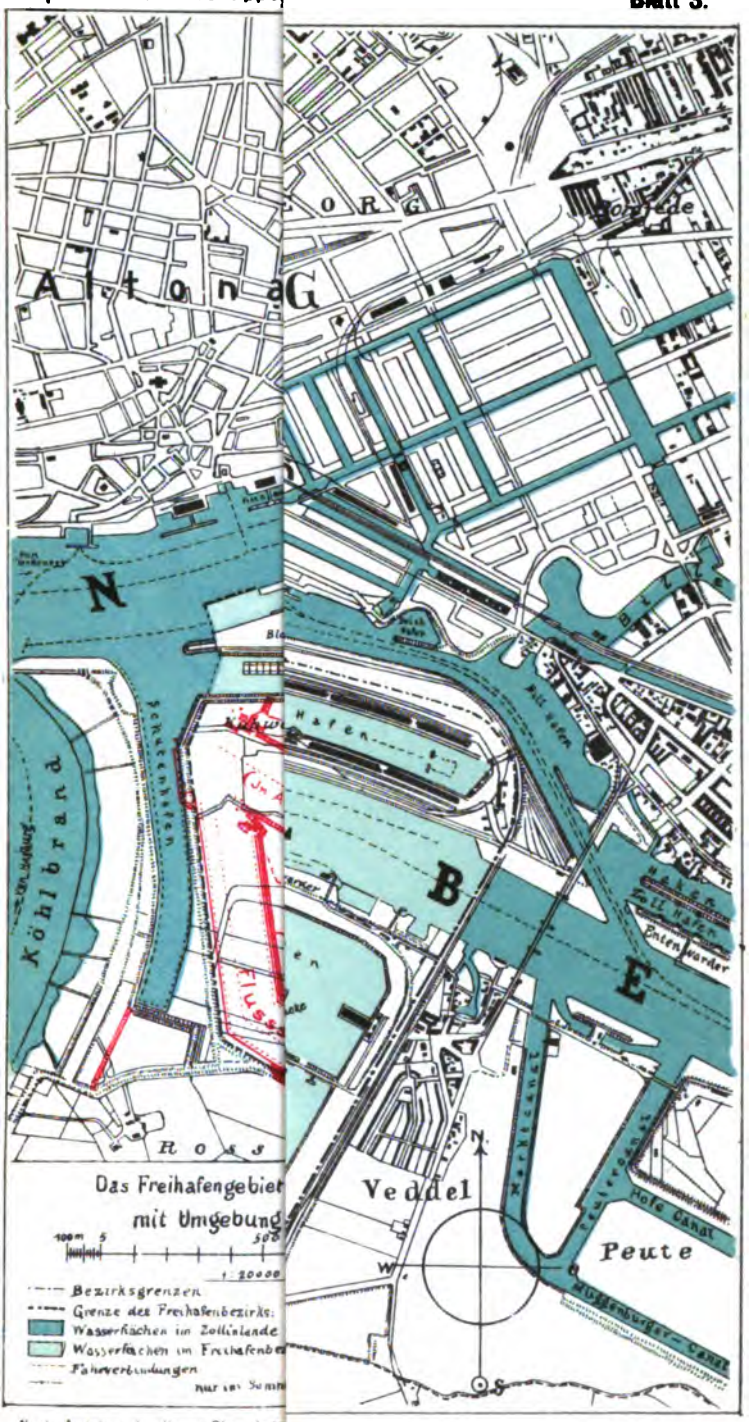
N°99

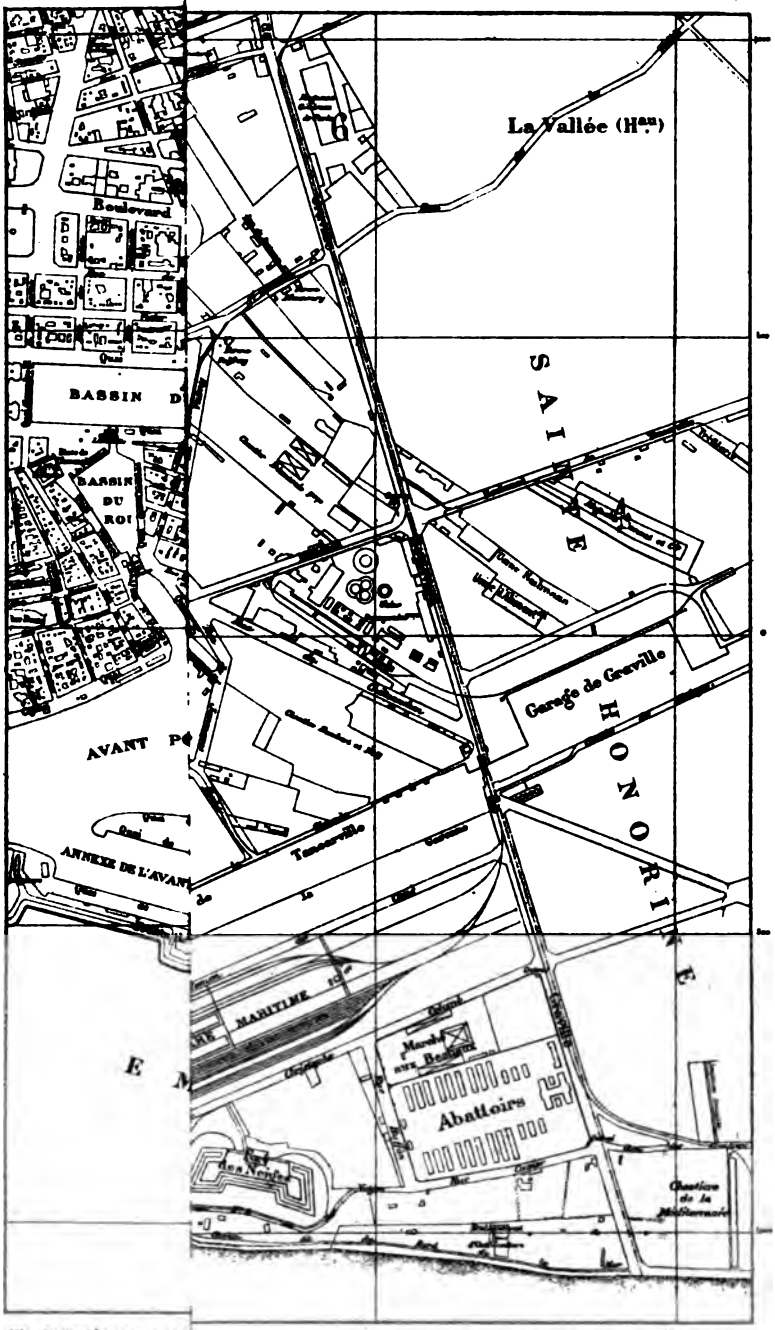
Speicher und Schuppe

Blatt 3.



Nach Angaben des Herrn Ober-Ingr

S Doc 30 56 1



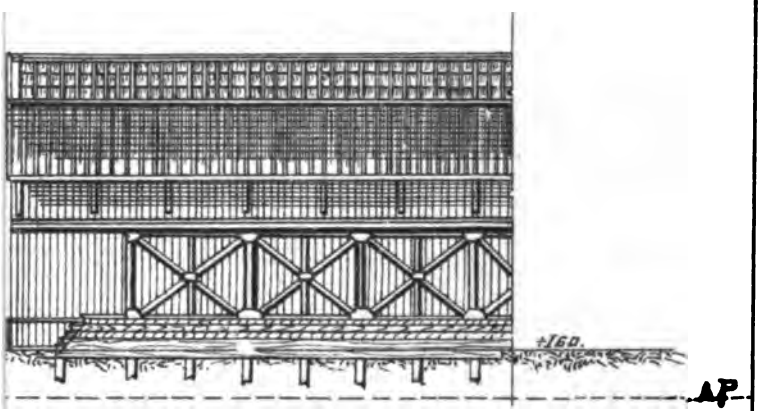
E

arville.

6. *Entrepôts et Magasins généraux de Paris*
7. *Docks de la Gare maritime*

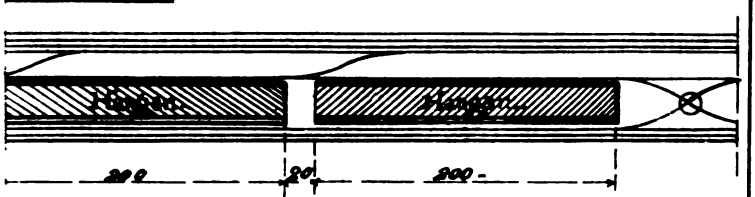
S Doc 30 56 1

N°105
Planche I.



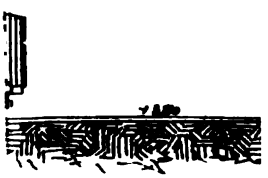
Situation.

elle : 1 à 5000



QUA RIEME SECTION. — 1e QUESTION.

S Doc 30 56 1



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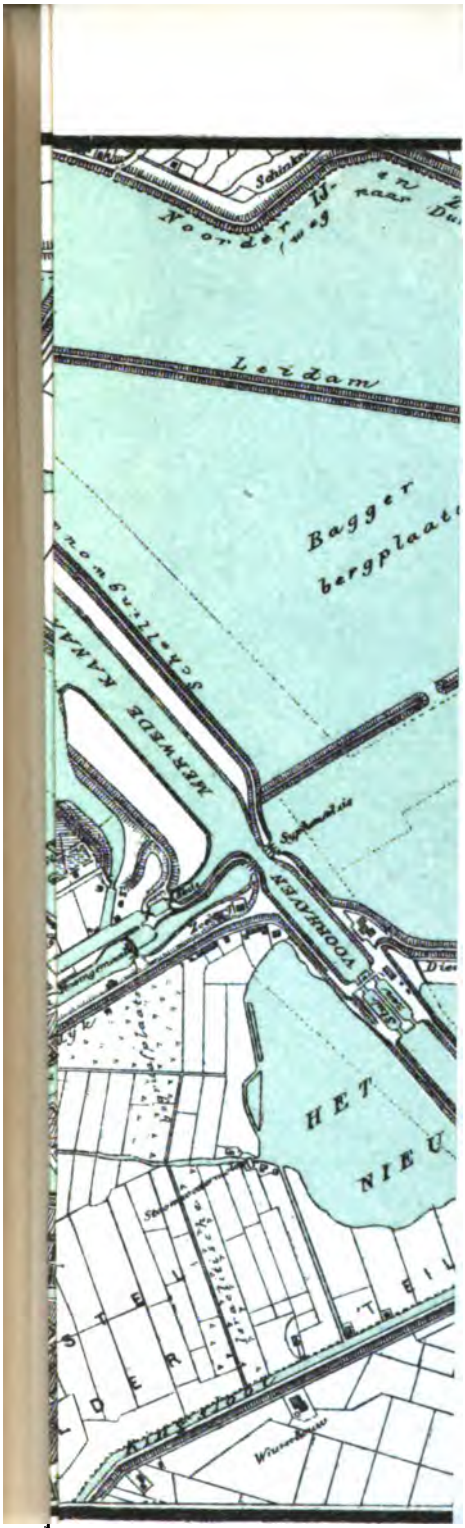
Leidam
Bagger
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MERWEDE KANAAL
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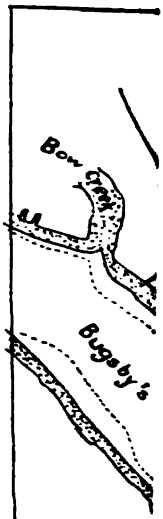
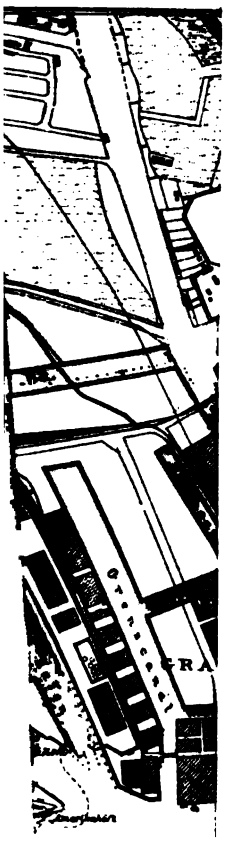
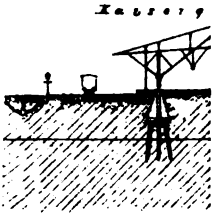

Bow Creek
Bugsby's

Ad. GU


H
St. Jacobi



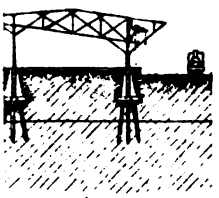
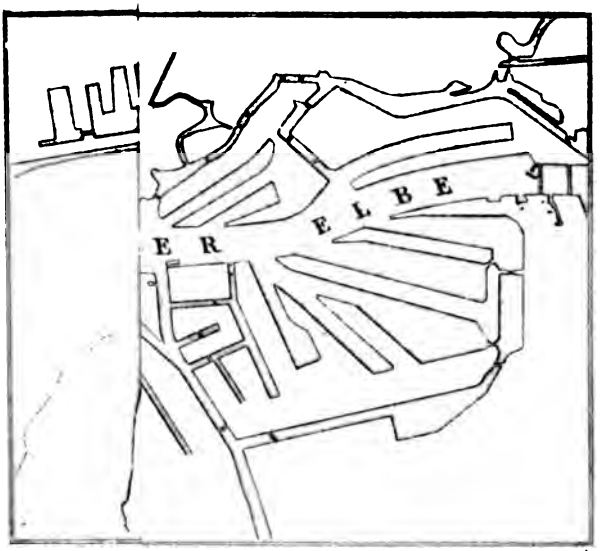


Planche 3.

AMBOURG. N° 112



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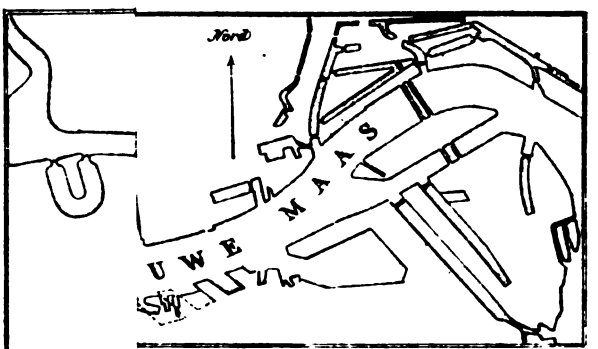

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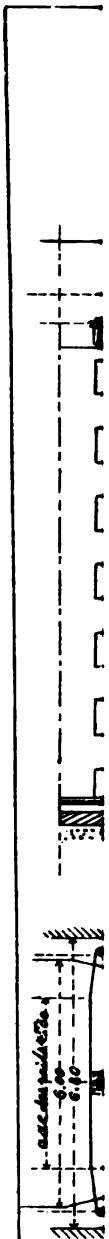
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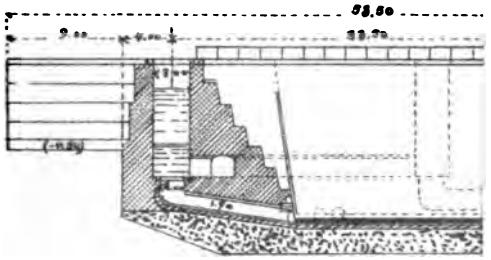
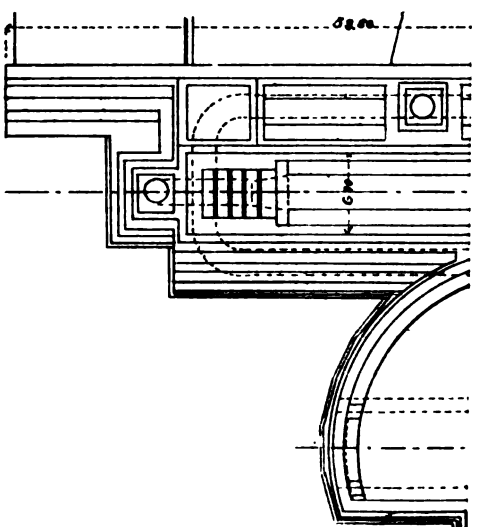
Écluse n°

Chambre des portes





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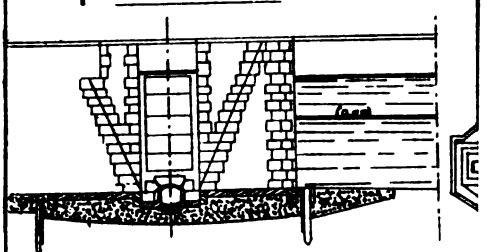

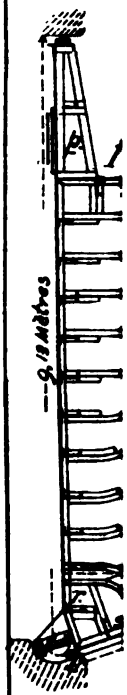

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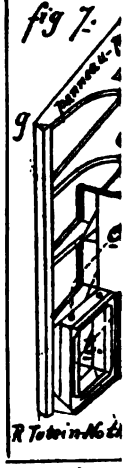

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NOV 23 1911